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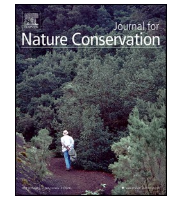

Stakeholder mental model analysis supports focused conservation policy and actions for Eurasian beaver (*Castor fiber*) reintroduction

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ABSTRACT

Eurasian beaver, *Castor fiber* has been restored to England's natural fauna following a trial reintroduction located in the country's southwestern region. Beavers characteristically generate profound and frequently beneficial shifts to river dynamics, nutrient cycling, biodiversity, and human cultural experience, but can also be associated with unwanted human interactions, impacts and costs. Consequently, an important objective of the trial design was to ensure conservation leadership, monitoring and mitigation for problems such as burrowing, damming and flooding, and damage to valued trees. To understand how these developments are perceived and accepted, implicated key stakeholder mental models were elicited and explored, using fuzzy cognitive map techniques. Analysis showed broad alignment of ecological understanding between stakeholders. Social perspectives showed marked divergence, a focus of concern as social conflict can undermine otherwise ecologically viable conservation benefits. To investigate perceived effectiveness of trial conservation measures, stakeholder models with and without conservation actions were experimentally compared under dynamic analysis. Overall, the findings indicate that actions taken are sustaining beaver acceptance and limiting persecution. Of stakeholder groups examined, farming appeared most susceptible to model divergence, but also strongly protected by mitigation. This is important as reconciling mental model differences is considered a necessary element in building socio-ecological system resilience. These findings highlight mental model analysis as a valuable aid to assessment of social dimensions of conservation policies. Further, mental modelling could help to focus how farm payment reform in the U.K. and similar economies might be used to support leadership and mitigation designed to improve human-beaver ecosystem resilience.

1. Introduction

In 2020, the U.K. Department for the Environment and Rural Affairs, with responsibilities in England, granted permanent status to a population of Eurasian beavers, *Castor fiber* living on the River Otter in Devon, Southwest England (DEFRA, 2020). This decision followed a 5-year monitored reintroduction, the River Otter Beaver Trial, ROBT (Brazier et al., 2020) informed by prior U.K. experience of reintroduction in Scotland (Gaywood et al., 2015), which has also been followed by formal native species recognition by the Scottish government (Scottish Government, 2016). As a programme of project management, the ROBT drew together a forum of expertise including Devon Wildlife Trust as principal conservation NGO, academic leadership from Exeter University, and associated conservation, landowning, management and public organisations. In addition to support for environmental monitoring including studies of biodiversity, hydrology and water quality, the Wildlife Trust developed and delivered conservation leadership, information and mitigation for stakeholders concerned about localised effects of beaver activity on river morphology, water levels and valued trees, Fig. 1.

For conservationists and land managers, beaver reintroduction and recovery continues to stir interest because of the significant wildlife and ecosystem service benefits associated with beaver presence (Law, Gaywood, Jones, Ramsay, & Willby, 2017; Puttock, Graham, Cunliffe, Elliott, & Brazier, 2017) as well as concern about the precarious state of English wetlands (Mainstone, Hall, & Diack, 2016). Typically, beaver reintroduction in the U.K. attracts public support, more so where the issues involved are better understood (Auster, Puttock, & Brazier, 2020),

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Fig. 1. Retained water behind a beaver dam (foreground) on a small tributary streamlet in the lower Otter valley. Monitoring equipment plus evidence of beaver felling are visible, (Photograph by first author, with kind permission of Clinton Devon Estates).

reflecting the lessons of effective leadership and consensual stakeholder awareness and participation as a basis for conservation acceptance (Jones-Walters & Çil, 2011). Nevertheless, reintroduction continues to be opposed by individuals and groups concerned about beaver interaction with current modes of agricultural production, fisheries and infrastructure.

Irrespective of how concerns or outright opposition to wildlife conservation initiatives are justified, the consequences are often framed in terms of human-wildlife conflict, defined as "any human and wildlife interaction which results in negative effects on human social, economic, or cultural life, or wildlife conservation, or on the environment" (United Nations Food and Agriculture Organisation). Balancing these perspectives, decision-makers are required to weigh the views of stakeholders whose values and attitudes to wildlife vary greatly (Kings & Ilbery, 2010), and whose adaptive capacity may be restricted (Mills, Gaskell, Ingram, Dwyer, Reed & Short, 2017).

As the ecological, ethical and legal case for beaver reintroduction into England is well documented (Gurnell et al., 2009), we focus on exploring how human-beaver interactions may be influenced by alignment or divergence of stakeholder perspectives in an environment where people have limited long-term cultural memory of beaver presence (Coles, 2006), and equally limited recent experience of coexistence. In considering conservation actions, scholars have increasingly sought to understand human perception, thought, emotion and behaviour in relation to nature (Fischer et al., 2011; Jacobs & Vaske, 2019; Mosimane, McCool, Brown, & Ingrebretson, 2014; Schenk, Hunziker, & Kienast, 2007), their insights contributing to understanding the influence of psychological factors within functional and resilience properties of socio-ecological systems (Hinkel, Bots, & Schlüter, 2014). We derive special inspiration from a paradigm-setting review (Walker et al., 2006) summarising psychological perspectives revealed within the theoretical framework of interacting mental models, "driv(ing) change in social-ecological systems, (of which…) adaptability is enhanced through partially overlapping mental models of system structure and function".

Mental models are defined as the "personal, internal representations of external reality that people use to interact with the world around them" (Craik, 1967; Jones, Ross, Lynam, Perez, & Leitch, 2011). As symbolic maps of perceived causal relationships and associations, mental models are as-if inference-mechanisms, and thus facilitate reasoning and decision-making. At a societal level, mental model 'overlap' or alignment applies mental model theory to modes of cooperative social adjustment, for example in wetland restoration (Olsson, Folke, & Hahn, 2004), economic development (Dubé, Addy, Blouin, & Drager, 2014), agri-policy (Vuillot et al., 2016), and fisheries (Lavin, Giabbanelli, Stefanik, Gray, & Arlinghaus, 2018). These studies indicate scope for enhanced and novel ways of exploring mental model overlap and divergence in support of wildlife conservation outcomes.

Approaches to examining mental models build on two decades of environmental mental modelling theory and research development combining approximative logic and cognitive mapping to generate fuzzy cognitive maps, 'FCMs' (Gray, Zanre, & Gray, 2014; Özesmi & Özesmi, 2003, 2004). As research tools, FCMs can be interpreted individually or in aggregate, and can be compared according to static properties based on mathematically defined graph theory measurements such as the connective salience of individual concepts, overall connective density and complexity of the model, degree of hierarchical structure, and model dynamic analysis (Byung Sung Yoon & Jetter, 2016). Dynamic analysis of expected model outcomes may in turn be adapted to simulate the effects of experimental policy alternatives, usually involving the addition of novel policy concepts and connections (Jetter & Kok, 2014; Kok, 2009).

Following the reasoning of Walker et al. (2006), mental model content incompatibility or divergence revealed by dynamic analysis is likely to increase the risk of conflicting human-wildlife interactions. Consequently, identification of model divergence may highlight potential threats to the long-term viability of sensitive conservation species such as the River Otter beaver population. Problems of mental model incompatibility undermining solutions to land degradation have been studied in detail (Abel, Ross, & Walker, 1998) and have remained an important research focus in the Australian context (Moon et al., 2019; Walker & Salt, 2006). Agricultural intensification and associated ecosystem stress including loss of resilience and extinctions are however global concerns (Rockström et al., 2009), only varying in pace and scale. This paper considers stakeholder differences and divergence analysis, and the role of a local wildlife NGO and its services in supporting a successful species reintroduction which has much wider implications for beavers and future wetland restoration in Europe. We pose two linked research questions (RQ):

RQ1. What stakeholder mental model content differences and dynamic divergences are identifiable in relation to beaver reintroduction and conservation?
RQ2. How effectively does project leadership and delivery of monitoring and mitigation help achieve mental model 'overlap' by resolving stakeholder divergence?

In this study, the research questions concentrate on beaver reintroduction and conservation in developed mixed landscapes such as those of lowland England, to our knowledge as yet unaddressed (Conservation Evidence Base, www.conservationevidence.com). They also highlight a more general role for 'policy removal' as a valuable experimental technique to examine relationships between policy and mental model alignment or divergence, explaining mechanisms for perceived outcomes of conservation decision-making.

2. Method

2.1. Geographic area

The study focuses on the ROBT reintroduction area. The mainstem of the River Otter is a small river running into the western English Channel from a total catchment of 250 km^2. The watershed includes two conservation 'Areas of Outstanding Natural Beauty' and an estuarine 'Site of Special Scientific Interest'. By completion of the ROBT in 2020, there were unofficially estimated to be up to 50 resident beavers creating patches of typical beaver wetland habitat. The riparian margin is primarily composed of grassland, with significant representation of arable

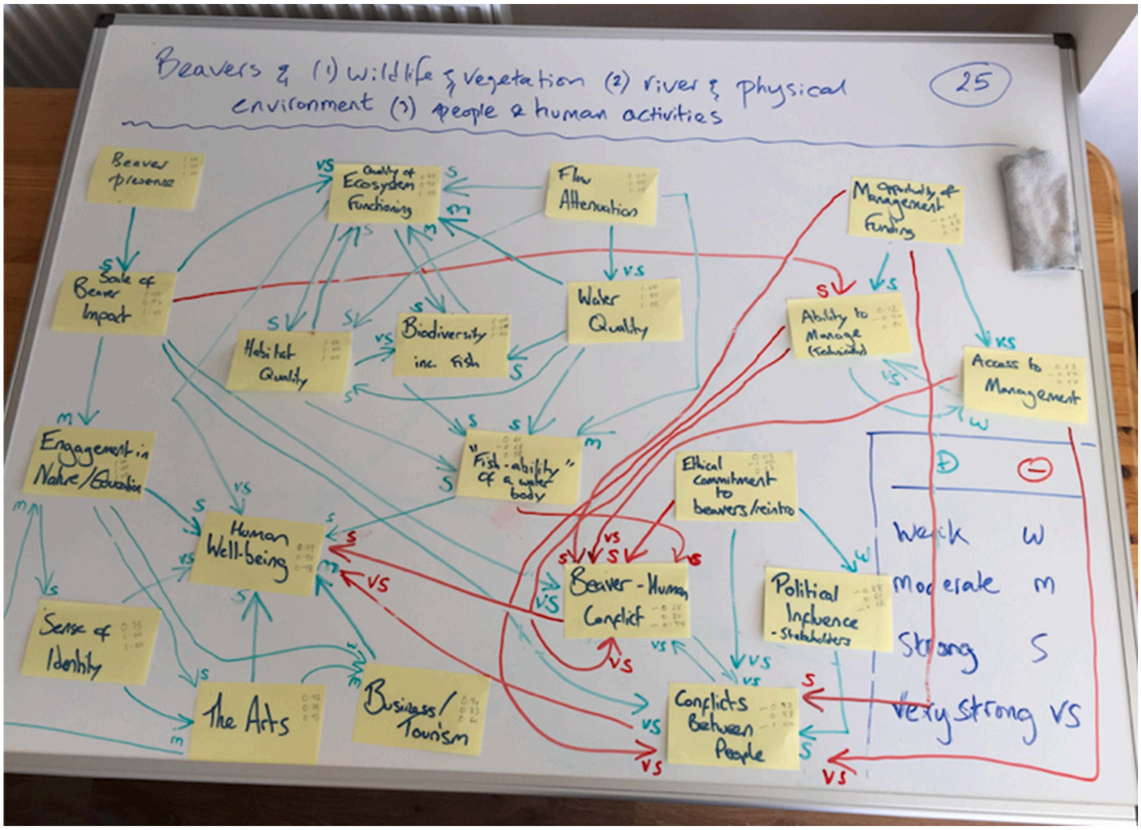

Fig. 2. Sample CES map, with thanks for the participant's kind permission.

and localised forestry, orchards, village and urban settlements [2].

2.2. Stakeholder sampling

Participants were recruited on the basis of (i) criteria of residence, work, conservation, academic or leisure participation in the ROBT area, and (ii) an occupational or self-declared interest in the trial during the five-year period up to expected completion in 2020. Each participant identified their own stakeholder group affiliation, using pre-determined category-terms decided through discussion with the ROBT project manager and review of annual ROBT reports later summarised by Brazier et al. (2020). Participants falling into five stakeholder categories were considered; General Public (GP, n = 21), Conservation and Environmental Scientists (CES, n = 9), Landowners and Managers (LM, n = 7), Farming (F, n = 3) and Angling (A, n = 4). Of these groups, the first three are large enough to explore aggregated FCMs, each representing a form of 'average' sectoral stakeholder perspective.

In this study, the approach is premised on using people's mental models as an expert information resource (Olazabal, Neumann, Foudi, & Chiabai, 2018) showing human-wildlife interactions and coexistence; thus sampling is deliberately targeted. We recruited (n = 25) participants via advertising on local community Facebook pages and Twitter, primarily interested members of the General Public as the potentially numerically largest stakeholder group. A similar number (n = 23) were recruited by direct approach and snowballing, including a larger proportion of 'specialist' stakeholders.

Of 'specialist' stakeholders, representatives of the Farming and Angling communities were most difficult to recruit. Anecdotally, peer group sensitivity may have been a significant barrier to participation, even with anonymity assured. As aggregation based on identifying more frequently mentioned concepts and averaging their connections is less feasible with very small samples, we instead selected single 'best qualified' Farming and Angling mental models, defined by criteria chosen to reflect active 'hands on' human-beaver coexistence; (i) direct experience with beavers and mitigation and (ii) mental model concept richness.

It was initially planned that overall sample size would be determined by detection of 'concept saturation' indicated by flattening of the new concept accumulation curve (Özesmi & Özesmi, 2004). In practice, we continued interviewing beyond this point because specialist recruitment progressed more slowly, requiring a more pro-active approach. Retrospective accumulation analysis showed overall 89% concept saturation achieved by 25/48 interviews.

2.3. Stakeholder mental model interview procedure

Mental model elicitation interviews conducted by the first author took place between October 2018 and May 2019, (mean 149 min, range 70–270), at homes or workplaces. In situ interviews in the presence of environmental cues is preferable (Jones, Ross, Lynam, & Perez, 2014), but impractical in winter.

Interviews commenced with a standardised explanation of procedure, academic affiliation, ethical standards, collection of identifier data, and presentation of photographs of a beaver, the river and a map of the trial area. Participants were given one mandatory concept, 'Beaver presence' and asked to lead in generating further concepts according to three framing categories; '(a) wildlife & vegetation, (b) river & physical environment, (c) people & human activities', considering a time frame – 'current' to 'the next five years.' Participants were encouraged to express concepts positively, for example 'tolerance' rather than 'intolerance'.

In practice, participants required process support met by a conversational method with participant concepts noted and shared back for accuracy. Participants were then asked to (i) write each concept using their own terms onto separate 'Post-its' distributed by the participant however preferred on a large whiteboard, (ii) to add (+) direct or (−) inverse signed arrows to represent the direction of perceived causal influence between as many pairs of concepts as desired, and (iii) to weight

Table 1
Concept list and categories, with numerical content showing stakeholder FCM concept sharedness frequency (*Concept category: S, Social; LN, Living nature; AN, Abiotic nature).

FCM Concept list	Concept Category*	General Public	Cons. Env. Science	Land. & Managers	Farming	Angling
Beaver presence – (Mandatory given concept)	LN	4	4	4	4	4
Beaver acceptance – Farmer, landowner, forestry	S	4	4	4	4	4
Biodiversity – general	LN	3	3	3		3
Science, education & knowledge	S	3	3		3	3
Government policy/finance for nature	S		3	3	3	3
Water retention – upper catchment	AN	3	3	3		3
Wetland – ecosystem health & services	LN	3	3	3		3
Riparian woodland/vegetation health	LN	2	2	2		
Holistic enrichment through valuing nature	S	2			2	2
Sense of place/specialness	S	2			2	2
Beaver acceptance – General public	S	2	2	2		
Wildlife NGO – effective leadership	S	2	2	2		
Conflict – public and private property/amenity	S	2	2		2	
Beaver damming and impoundment of water	AN	2		2		2
Nature tourism	S	1	1			
Beaver flooding/impact on productive land	AN	1	1			
Making space for wilder nature	S	1	1			
Beaver acceptance – Anglers	S		1			1
Monitoring & mitigation	S			1	1	
Natural hydrology – wilder river	AN				1	1
Business generation	S	1			1	
Flow rate/problem flooding in lower reaches	AN	1				1
Conflict & distress – natural resource stakeholder	S		1			1
Perception of 'legal over-protection'	S				1	1
Public health & well-being	S					0
Water quality	AN				0	
Public access	S					0
Fish population health	LN					0
Farm production – income	S				0	
Direct beaver impact – other costs	S				0	
Beaver persecution	S		0			
Agri-business viability & jobs	S				0	
Mean frequency of concept sharedness per Stakeholder FCM		2.17	2.12	2.64	1.60	1.89

each arrow using 'fuzzy' semantic labels representing strength of effect; Very Strong 'VS', Strong 'S', Moderate 'M', and Weak 'W'. A sample completed map generated by a conservation scientist is shown in Fig. 2.

2.4. FCM generation and aggregation

Mental model conversion to FCMs (Gray et al., 2014) followed published environmental study methods (Obiedat & Samarasinghe, 2016; Olazabal et al., 2018; Özesmi & Özesmi, 2004). The procedure is summarised as: (i) standardisation and reduction of 'raw' terms to 'condensed' semantically equivalent FCM concepts, (ii) conversion into square matrices populated with numerical values representing connection weights: 'VS, 0.8; 'S', 0.6; 'M', 0.4; 'W' 0.2, and (iii) in the case of merged or aggregated models, concatenation to multiple values in each cell averaged to produce a mean weight (Abel, Ross, & Walker, 1998; Cannon-Bowers & Salas, 2001; Gray et al., 2014), followed by (iv) allocation of initial 'concept activation values' for dynamic analysis of intermediate and final stabilised concept values.

The initial sample of 48 models comprised 657 'first order' concept terms (mean per model 13.3, range 8–24). Initial processing included merging of 16 pairs and 1 triplet of closely allied terms within models. 22 negative terms plus 2 merged negative term pairs were inverted for consistency. Aggregated terms were then aligned under 53 'second order' condensed concept headings recognised by semantic equivalence, defined on inspection by the first author as accumulation proceeded. For example, four tourism terms: 'Tourism', 'Beaver tourism', 'Hospitality/Hotel sector', and 'External tourism' were merged into 'Nature tourism'. In the case of merged concepts resulting in duplicated connections, the most strongly weighted connection was retained for subsequent dynamic analysis of aggregated models.

Aggregation procedures are not standardised in the literature; methods advocated include assembling all concepts with retention of the strongest summated connections (Özesmi & Özesmi, 2004) or inclusion by weighting for expert credibility (Obiedat & Samarasinghe, 2013). In this study, the goal of aggregation was to generate an 'average' stakeholder group perspective. To generate a shared stakeholder group FCM, concepts were retained above the median quartile ranked by frequency mentioned, which delivered model sizes suited to interpretation (Özesmi & Özesmi, 2004). Mean connection values were calculated by excluding zerosv and applying an inclusion threshold to ensure minimum frequencies and directional consistency of connections between retained concepts for each aggregated group; (i) GP, minimum of three same-signed connections or four connections with a maximum of one discrepant sign removed prior to calculation of a mean value, (ii) CES as GP, (iii) LM, minimum of two same-signed connections, otherwise as GP. Orphan concepts left unconnected were retained but do not participate in dynamic interactions.

2.5. FCM dynamic analysis

Dynamic analysis evaluates stakeholder FCM outputs by 'loops' of iterative multiplication of the set of concept activation values by the connection matrix constructed from each FCM using the Microsoft Excel MMULT function, until a stable set of activation values indicate relative semi-quantitative outcomes (Kok, 2009). Initial activation values of 1.0 and self-connection weights of 1.0 were attributed to concepts lacking inputting connections, which function as stable 'transmitters.' As no dynamic normalisation was applied and models behaved exponentially under feedback influences, interpretation was assisted by clamping 'Beaver presence' activation at 1.0 which stabilised concept outputs for all five stakeholder FCMs.

Dynamic outputs were interpreted as: 1 fully active, >1 growing and influential, 0–1 modest to moderately active, 0 inactive and <0 actively inhibited. The spread of results represents the relative functional prominence of concept activations for each FCM.

2.6. Comparing FCMs

Three frequently cited approaches to FCM comparison were considered (Byung Sung Yoon & Jetter, 2016);

1. Content; FCMs compared by concept presence and absence to identify the extent of shared or unique stakeholder concept preoccupations.
2. Structure; FCM concept and connection counts, connective density (ratio of connections to all possible connections) and concept influence or centrality (sum of inputs and outputs).
3. Dynamic analysis; intermediate and 'final response profile' activation values can be compared by allowing FCM concepts to interact until a stable set of values emerge, with or without normalisation and/or clamping of drivers to vary starting conditions.

Content comparison and dynamic analyses showing overlap or divergence of concept activation outputs are heuristically meaningful for our sample; structural metric comparisons were not made because of aggregation applied in some but not all cases.

2.7. 'Experimental' FCM dynamic analysis used for RQ2

The concepts 'Wildlife NGO – effective leadership' (NGO) and 'Monitoring and mitigation' (M&M) and their connections occurred in General Public, Conservation and Environmental Science, Landowners and Managers, and Farming, while absent in Angling which consequently cannot contribute to analysis. To address RQ2, the concepts NGO and M&M were removed to create 'experimental' FCMs comparing transient and final dynamic outputs with their unmodified controls, disregarding trivial output differences defined as $<10\%$.

3. Results

3.1. RQ1. What stakeholder mental model content differences and dynamic divergences are identifiable in relation to beaver reintroduction and conservation?

Concept sharedness was defined as the number of additional FCMs with the same concept. Mean stakeholder group concept sharedness was ordered LM > GP > CES > Angling > Farming. Model concepts categorised as living nature (LN), abiotic nature (AN) or social (S) were compared according to ecological and social dimensions used in elicitation. At the extremes, Landowner and Managers showed the least distinctive content, while Farming contained more unique concepts and a greater proportion of social concepts of which 3 of 4 were distinctively sectoral relating to agricultural activity and business. Concept categories and Stakeholder FCM sharedness are shown in Table 1.

Dynamic concept activation outputs for each stakeholder group FCM are shown in the Appendix, Table 2.

3.1.1. Living nature dimension: Wildlife and vegetation

Living nature concepts concerning wildlife including vegetation and ecosystem health were strongly present and shared by General Public (GP), Conservation and Environmental Science (CES), Landowners and Managers (LM), and Angling; the latter with an unsurprising sectoral bias towards fish. The Farming model differed from others by paying less attention to wild nature itself than to nature appreciation in the Social dimension. Dynamically, the Living Nature concept 'Biodiversity – general' showed absolute expansion in GP and LM groups, while a set of Living Nature concepts showed similar expansion in Fishing. CES viewed these concepts developing more modestly. Farming's sole concept in this category was the universally shared mandatory concept "Beaver presence", clamped at fully active.

3.1.2. Abiotic nature dimension: River and physical environment

Abiotic nature concept variables concern the hydrological results of damming: water retention, modulation of flow and improvements in water quality. All models showed changes to river behaviour, albeit more generically in the case of Farming and much more concerned with detail in Angling. Beaver-induced local flooding effects were an unconditional driver in the CES model, spreading into the social dimension given that flooding tends to be defined as water where it 'shouldn't be' according to human-use criteria. The GP model laid emphasis on the consequences of flow regulation with favourable impact on problem-flooding affecting human population centres on lower reaches, prominent in the public-facing case made for reintroduction (Auster, 2019; Brazier et al., 2020).

3.1.3. Social dimension: People and human activities

Total social concept mentions, $n = 48$ concerning human experience, attitudes, behaviour and interactions examined across all five stakeholder groups were considerably more numerous than both nature concept groups combined, $n = 31$. Social concept mentions exceeded all nature concept mentions combined in four stakeholder categories with the following ratios; CES 11:6, Farming 12:3, Angling 10:8, GP 10:8, but not LM, 5:6; Total 48:31. The range of social concept categories included in the 'mentions', $n = 21$ exceeded the combined nature concept categories, $n = 11$. Dynamically, social concepts showed a general trend to higher activation levels; social concepts consistently exceeded combined nature concepts for those concept mentions for which dynamic output showed absolute expansion, shown in all stakeholder categories with ratios as follows; GP 5:1, LM 3:2, CES 1:0, Farming 2:0, Angling 5:4.

Qualitatively, strengthening psychological place attachment, a strongly emotional variable, showed growth over time for GP, Farming and Angling. Opportunities from enriched landscape and wildlife experience represented by tourism and business appeared strongly for GP and moderately for Farming. Expectations for Government policy and finance showed increasing prominence over time, for LM and Angling emerging strongly, for CES moderately so. Farming envisaged modest decline in farm production and expected only modest support for agri-business employment, while net beaver-related costs show marginal downward pressure. GP, LM, Farming and Angling envisaged beaver acceptance strengthening in one or more stakeholder groups, a view shared modestly by CES. In GP, stronger acceptance contrasted with expected falls in acceptance amongst 'Farmers, landowners and foresters.' CES foresaw strengthening wildlife NGO leadership. As M&M expertise within the ROBT catchment is coordinated by the NGO, expectations of the NGO role were consistent, with positive expectations of M&M shown in the LM and Farming models.

Indicators of emergent conflict included moderate concern about 'legal over-protection' in Farming, which appeared to be off-set by the availability of M&M. CES and Farming viewed stakeholder conflict and distress as moderately active, considered a stable driver by Angling. CES envisaged beaver persecution strongly inhibited and Angling viewed perceived over-protection as declining.

3.2. RQ2. How effectively does project leadership and delivery of monitoring and mitigation help achieve mental model 'overlap' by resolving stakeholder divergence?

Experimental removal of NGO and M&M may reveal (i) reverse in direction of dynamic concept activation and (ii) maintained direction but significant activation variation (iii) no change. Comparisons with unmodified controls are illustrated in Table 1. Results show that the impact of removing NGO and M&M concentrated in the CES and Farming models. This finding reflected the more immediate and direct involvement of CES and Farming stakeholders in the organisation and delivery of beaver mitigation. Maps showing concept variables and directed causal influences altered by the presence or absence of experimental conditions are themselves heuristically valuable, shown as

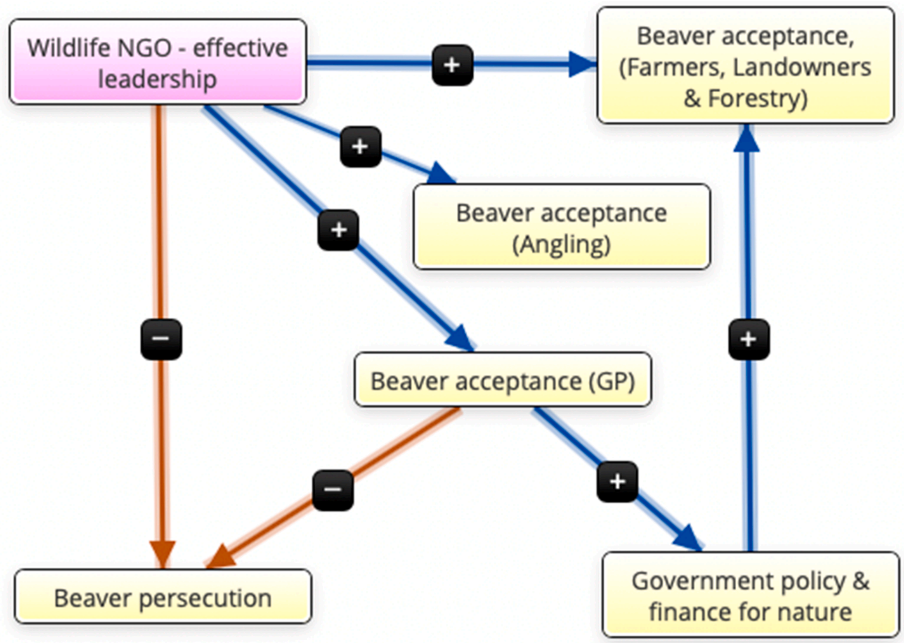

Fig. 3. Conservation and Environmental Scientists (CES); NGO influence.

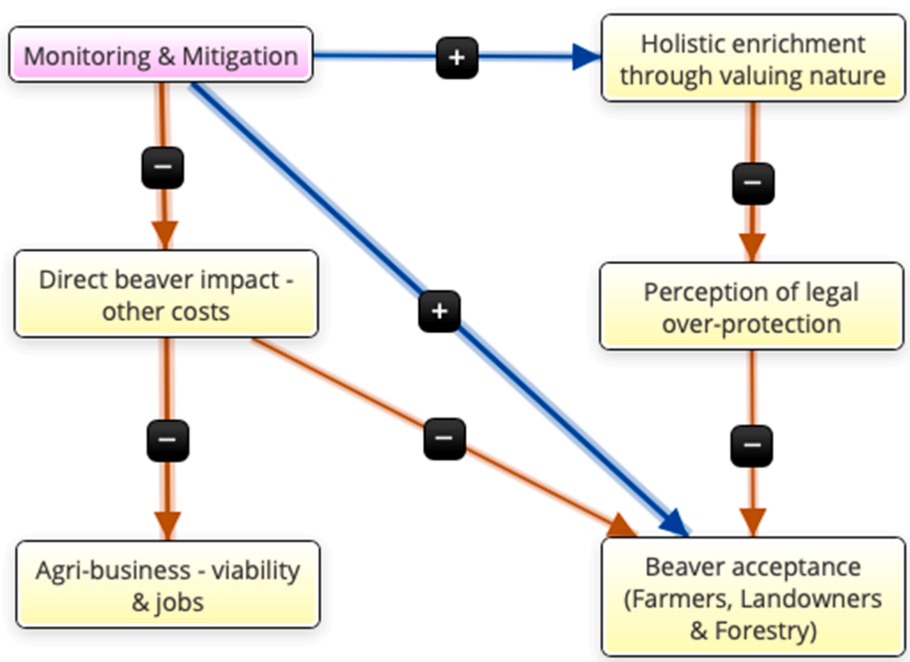

Fig. 4. Farming; Mitigation & Monitoring (M&M) influence.

extracts from the CES FCM, Fig. 3, and Farming FCM, Fig. 4, made on publicly available Mentalmodeler software, (Gray, Gray, Cox, & Henly-Shepard, 2013; www.mentalmodeler.com, with thanks).

The CES FCM showed positive NGO influences on three stakeholder beaver acceptance concepts suggesting strong project confidence, an interpretation reinforced by inverse influence on beaver persecution indirectly suppressed via increased general public beaver acceptance. Mechanisms underlying beaver persecution inhibited by public acceptance cannot be assumed. Public support may also influence pro-nature Government policy, in turn stimulating land-user acceptance, probably mediated by anticipated farm payment reform.

The Farming FCM showed positive M&M influence on beaver acceptance consistent with the CES view of the NGO role, indicating that farmers and conservationists share confidence in NGO delivery of M&M. M&M suppressed farm costs, with potentially favourable impact on employment. M&M also promoted psychological benefits for farmers and/or wider society (the model does not allow us to be clear which), perhaps by reducing farmer ambivalence about wildlife, if wildlife and agri-production are seen as more compatible in a less conflicted landscape. Satisfaction in nature also reduced concern over loss of autonomy represented by perceived legal over-protection, in turn inversely supporting farmer acceptance of beavers.

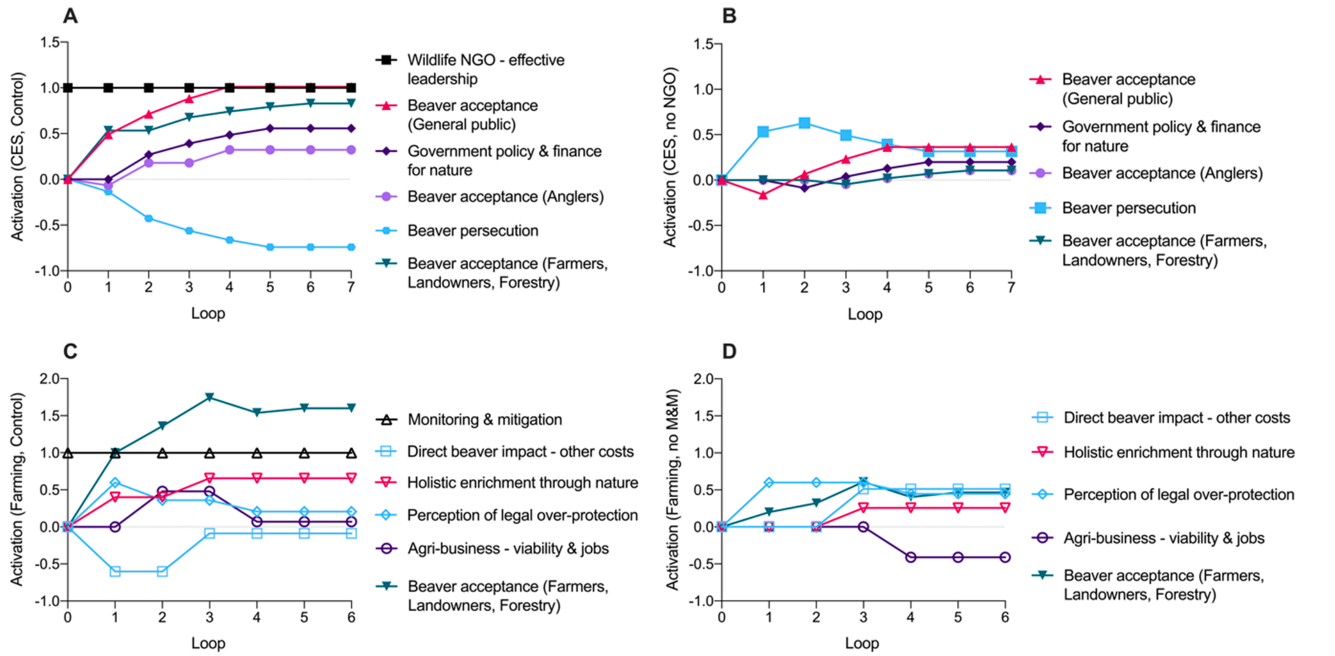

Fig. 5. CES 'control' (A) v. 'NGO leadership removal (B); Farming 'control' (C) v. 'M&M removal' (D). Thanks to Jerome Blewett for help with figure creation.

3.2.1. *Evolution of concept activation values*

Dynamic analysis of CES and Farming FCMs illustrating strikingly more marked divergence and unfavourable outcomes when ROBT NGO and M&M are experimentally removed, compared with controls, is illustrated in Fig. 5. GP and LM models show analogous trends with loss of favourable growth in beaver acceptance when NGO and M&M are removed.

The CES control chart, Fig. 5A shows favourable NGO impacts and a more highly responsive chart with confident conservation progression following rapidly resolved early phase loss of angler confidence. The evolution of concept values altered by the presence or absence of NGO is strikingly shown in the experimental CES with NGO removed, Fig. 5B, with an early rise in persecution corresponding to negative stakeholder acceptance followed by attenuation and modest favourable acceptance as government support emerges.

Analysis of the Farming control FCM with M&M retained, Fig. 5C shows an early decline in costs not fully sustained, perhaps reflecting increasing complexity of beaver management. Job creation could be seen as mitigation-related and potentially funded by farm payments, or by expansion within the existing farm business model. Perceived 'legal over-protection' indicating anxiety over loss of autonomy rises early then falls step-wise as costs remain under control while acceptance and psychological benefits grow, which may suggest expanding confidence in coexistence. The experimental Farming scenario with M&M removed, Fig. 5D, shows a more alarming perspective. The business model appears depressed and costs remain elevated. Persecution rises early and remains prominent. Stakeholder acceptance and psychological benefits perhaps surprisingly remain positive after cautious early growth.

4. Discussion

The principal findings of interest from our investigation into stakeholder mental model content and dynamic response profiles for an English beaver reintroduction project are as follows:

(i) Social concepts tended to be (a) more numerous and (b) show more sectoral specificity than living and abiotic nature concepts.

(ii) Conversely, living and abiotic nature dimensions of mental models showed a generally shared 'overlapping' understanding across the stakeholder community.

(iii) Implementation of NGO leadership and monitoring and mitigation appear to reduce adverse dynamic divergence between expected stakeholder social and economic outcomes.

4.1. *Predominance of social content*

In this study, when people are asked to outline how they think about a nature-centred question, their mental models are dominated by social interactions and outcomes. As a species, humans are intensely concerned with social transactions lending support to individual and group survival involving questions of hierarchy, cooperation and adaptive success (Cummins, 2000; Dunbar, 2014). Human relationships with nature appear strongly socially contingent: for example, how nature is viewed and understood in relation to social factors underpinning use including values and normative beliefs (Teel et al., 2010), with implications for ownership recognition and definition, granting of permissions, agreement on trade-offs, valuing of landscapes and so on. It is also increasingly apparent that human emotion plays a significant role in regulating cognitive aspects of nature relationships (Jacobs & Vaske, 2019), and may signal concept salience in wildlife conservation mental models (Blewett et al., 2021).

An important research inference is that conservation planning requires a correspondingly rich social analysis, for which the research literature suggests mental modelling can be an informative and effective tool (Moon et al., 2019). Conservationists increasingly recognise the importance of social factors, illustrated by the CES group FCM in this study, in which 9 of 15 concepts can be defined as 'social', increased to 11 if the social dimensions of farmland flooding and ecosystem services are considered definitive. Thus, conservation is understood as heavily dependent on human preferences, responsibilities, choices and interactions (Kareiva & Marvier, 2012), challenging human societies to identify and implement new ways for people and nature to coexist sustainably (Buscher & Fletcher, 2020), based on paradigms in which the real value of nature is recognised (Fernandes, Guiomar, & Gil, 2019).

4.2. Mental models and dynamic divergence

Compared to social concepts, stakeholder understanding of beaver ecology and physical impacts affecting habitat, hydrology, wildlife and vegetation align well; content and relative activation trends taken at face value for living and abiotic nature themes shown in the Appendix Table 2 suggest no fundamental incompatibilities. For example, the social concept 'Beaver acceptance - Farmers, Landowners & Forestry' shows absolute increase for Landowners and Managers but the opposite for the General Public; there are no such contradictory outcomes for nature concepts. GP and CES show an especially rich shared understanding of beaver interactions in nature, although precisely how information is shared between them is unclear. Interestingly in a study of Scottish forest diversity, Fischer & Young (2007) found well developed notions of biodiversity and interactivity external to scientific paradigms amongst non-specialist citizens, suggesting that informal routes to shared knowledge are important.

The Farming model is especially weighted to social content, showing two hydrological concepts plus mandatory 'Beaver presence', as opposed to twelve social concepts; a higher ratio than other stakeholder groups. This disparity might be explained by the pressure of business concerns unique to farmers surfacing more readily. If so, the presence of 'Sense of place – specialness' and 'Holistic enrichment through valuing nature' for Farming take on particular significance as nature-experiential social concepts. In practice, while farmers may appear to polarise in their attitudes towards production or conservation-oriented methods (Beedell & Rehman, 2000; Burton, Kuczera, & Schwarz, 2008), motivation to adopt pro-nature methods is complex, including economic incentives sensitive to personal circumstances, and social reinforcement from peers and others (Darragh & Emery, 2018; Kings & Ilbery, 2010; Lastra-Bravo, Hubbard, Garrod, & Tolón-Becerra, 2015; Marr & Howley, 2019). These studies suggest that mental models have potential to reveal detailed insights into how external factors interact with internal values and attitudes.

Divergent outcomes include differing expectations of beaver acceptance. GP pessimistically expects a striking inhibition of 'Beaver acceptance Farmers, Landowners & Forestry', contrasted with absolute increases in both the LM and Farming models, and moderate increases in the CES and Angling models. Stakeholder expectations also diverge for 'Perception of legal-overprotection', moderately active in the Farming model but inhibited in the Angling model. During the ROBT, farmers and landowners were free to remove unwanted dams, with protected status yet to be clarified. One version of how this situation might evolve is indicated by the Scottish strategy of protection plus licensed lethal and non-lethal intervention (NatureScot), which might be viewed as an attempt to satisfy divergent interests.

4.3. Bridging gaps between conservation objectives and sectoral stakeholders

Increased social concept divergence shown by dynamic analysis following experimental removal of NGO leadership is compatible with an important wildlife NGO conservation rapprochement role as a "trusted agency" delivering reliable mitigation (Bruskotter & Wilson, 2014) sensitive to local values and priorities (Straka, Bal, Corrigan, Di Fonzo, & Butt, 2018). The inferential method used compares well with accounts of scenario studies relying on the introduction of novel policies and connections (Kok, 2009; Diniz, Kok, Hoogstra-Klein, & Arts, 2015), as 'concept removal' minimises researcher assumptions.

In the ROBT, an NGO primarily funded by local membership and donations undertook the leadership and mitigation roles described, although it is possible to envisage other forms of provision in the future, perhaps contracting with independent beaver mitigators described in a North American context (Goldfarb, 2018). Current agri-environment policy proposals in England emphasise funding for sustainable land use, wildlife recovery and ecosystem restoration (DEFRA b), potentially offering a route to payments for novel and emerging services such as beaver mitigation.

This study highlights a Farming FCM showing positive engagement with the objectives of the ROBT, and therefore we believe demonstrating the most promising way forward for successful conservation outcomes. Even so, our findings suggest that of the sectors examined, the Farming model shows concrete reasons why farmers may be most vulnerable to divergence from social consensus on beaver conservation. Serious differences in confidence over beaver acceptance and fragile business outcomes implicate Farming more than other stakeholders, inferring an increasing risk of conflict for farmers if not successfully managed, a conclusion fully consistent with qualitative findings supporting mitigation for farmers (Brazier et al., 2020).

4.4. Wider contextualisation of the findings

The findings of this paper support recent work expanding environmental FCM research beyond analysis based on graph theory metrics towards a more detailed examination of conceptual content and perspective (Metzger, Gray, Douglas, Kirshen, & Haigh, 2019), including future-scenario dynamic analysis in which ecological and social variables can be seen to interact strongly resulting in relative variations in their activity and outcomes (Diniz et al., 2015). It also aligns with empirical findings showing the importance of social factors in perceptions of conflict in conservation (Dickman, 2010), and more broadly, the role of social science in securing conservation goals (Bennett et al., 2017).

Consistent with our findings, mental model and FCM research exploring a diversity of species and stakeholders has shown potentially conflicting social concepts driving outcomes in sensitive ecosystems with a strong conservation focus, for example a study of watershed management in Switzerland (Gaus, Grêt-Regamey, & Buchecker, 2021). Interactions showing perceived dominance and greater discordance amongst social concepts interacting with ecological processes have also been found in diverse cultural settings, for example, bushmeat harvesting in Tanzania (Nyaki, Gray, Lepczyk, Skibins, & Rentsch, 2014), mental model analysis to facilitate forest and Ethiopian wolf, *Canis simensis* conservation (Steger et al., 2021), and understanding the role of human cultural factors in securing long-term sustainability for the Atlantic cod, *Gadus morhua* fishery in the western Baltic (Schwermer et al., 2021).

Mental modelling methods complement parallel approaches to conservation psychology. The 'human dimensions of wildlife' formulation of value and attitude theory known as 'cognitive hierarchy' has increased understanding of how the variance in support for wildlife is distributed (Fulton, Manfredo, & Lipscomb, 1996; Manfredo, Berl, Teel, & Bruskotter, 2021; Zinn, Manfredo, & Vaske, 2000), documenting shifts in values informing wildlife attitudes and building models explaining support for controversial reintroductions. These findings, reliant on surveys, suggest that value and belief linkages amenable to learning effects and present in people's mental models (Biggs et al., 2011), indicate a basis for future work on synthesis in theory, data collection methods and analysis.

A recurring conservation theme is a mismatch between threats to nature and remedial policy effectiveness, often attributable to social factor discordance (Xu et al., 2021). As a social-dimension conservation tool, we believe that the relatively straightforward post hoc checking of perceived policy impact in mental modelling shown here is a pragmatic complement to methods dependent on funding, organisation and delivery of resource-hungry interventions such as workshops, focus groups and follow up interviews to deliver a complete change cycle (Abel et al., 1998; Biggs et al., 2008).

5. Conclusions and recommendations

In an assessment of the River Otter Beaver Trial, England's first free-

Table 2
Stakeholder FCM showing (i) conceptual content including 'transmitter' status where relevant (ii) control dynamic final response profile outcomes, (iii) experimental dynamic final response profile outcomes, (iv) concept category.

1. General Public – aggregated (GP): concept variable	Stable outcome value (loop 7)	Significantly altered outcomes (NGO removed)	Concept category: Social (S), Living (LN) or Abiotic Nature (AN)
Beaver acceptance – General public	3.76	3.02	S
Nature tourism	2.92		S
Sense of place/ specialness	2.75		S
Biodiversity – general	1.78		LN
Business generation	1.74		S
Science, education & knowledge	1.35		S
Beaver presence – (Given) (Clamped as transmitter)	1.00		LN
Holistic enrichment through valuing nature (Transmitter)	1.00		S
Wildlife NGO – effective leadership (Transmitter)	1.00		S
Conflict & distress – natural resource stakeholder (No connections)	1.00		S
Beaver damming and impoundment of water	0.79		AN
Riparian woodland/ vegetation health	0.72		LN
Making space for wilder nature	0.68		LN
Wetland – ecosystem health & services	0.60		LN
Water retention – upper catchment	0.43		AN
Beaver flooding/impact on productive land	0.37		AN
Flow rate/Problem flooding in lower reaches	−0.66		AN
Beaver acceptance – Farmer, landowner, forestry	−0.69		S
2. Landowner & Managers – aggregated (LM): concept variable	**Stable outcome value (Loop 25)**	**Significantly altered outcomes (NGO, M&M removed)**	**Concept category: Social (S), Living (LN) or Abiotic Nature (AN)**
Government policy/ finance for nature	6.73		S
Biodiversity – general	5.16		LN
Beaver acceptance – Farmer, landowner, forestry	3.72	2.97	S
Beaver acceptance – General public	3.52		S
Water retention – upper catchment	1.30		AN
Beaver presence – (Given) (Clamped as transmitter)	1.00		LN
Wildlife NGO – effective leadership (Transmitter)	1.00		S
Wetland – ecosystem health & services	0.80		LN
	0.75		AN

Table 2 (*continued*)

1. General Public – aggregated (GP): concept variable	Stable outcome value (loop 7)	Significantly altered outcomes (NGO removed)	Concept category: Social (S), Living (LN) or Abiotic Nature (AN)
Beaver damming and impoundment of water			
Monitoring & mitigation	0.70		S
Riparian woodland/ vegetation health	0.65		LN
3. Conservation & Environmental Scientists – aggregated (CES): concept variables	**Stable outcome value (Loop 7)**	**Significantly altered outcomes (NGO removed)**	**Concept category: Social (S), Living (LN) or Abiotic Nature (AN)**
Beaver acceptance – General public	1.01	0.36	S
Beaver presence – (Given) (Clamped as transmitter)	1.00		LN
Beaver flooding/impact on productive land (Transmitter)	1.00		AN
Wildlife NGO – effective leadership (Transmitter)	1.00		S
Conflict – public and private property/ amenity (No connections)	1.00		S
Beaver acceptance – Farmer, landowner, forestry	0.83	0.11	S
Science, education & knowledge	0.80		S
Biodiversity – general	0.71		LN
Nature tourism	0.60		S
Making space for wilder nature	0.60		LN
Government policy/ finance for nature	0.56	0.20	S
Conflict & distress – natural resource stakeholder	0.53		S
Riparian woodland/ vegetation health	0.50		LN
Wetland – ecosystem health & services	0.36		LN
Beaver acceptance – anglers	0.32	−0.01	S
Beaver persecution	−0.74	0.32	S
4. Farming: Concept variable	**Stable outcome value (Loop 6)**	**Significantly altered outcomes (M&M removed)**	**Concept category: Social (S), Living (LN) or Abiotic Nature (AN)**
Beaver acceptance - Farmer, landowner, forestry	1.60	0.46	S
Sense of place/ specialness	1.08		S
Beaver presence – (Given) (Clamped as transmitter)	1.00		LN
Science, education & knowledge (Transmitter)	1.00		S
Monitoring & mitigation (Transmitter)	1.00		S

(*continued on next page*)

Table 2 (*continued*)

1. General Public – aggregated (GP): concept variable	Stable outcome value (loop 7)	Significantly altered outcomes (NGO removed)	Concept category: Social (S), Living (LN) or Abiotic Nature (AN)
Government policy/ finance for nature (Transmitter)	1.00		S
Natural hydrology – wilder river	0.80		AN
Holistic enrichment through valuing nature	0.66	0.26	S
Conflict – public and private property/ amenity	0.64		S
Water quality	0.32		AN
Perception of legal over-protection	0.21	0.45	S
Business generation	0.20		S
Agri-business viability & jobs	0.07	−0.41	S
Direct beaver impact – other costs	−0.09	0.51	S
Farm production – income	−0.32		S
5. Angling: Concept variable	**Stable outcome value (Loop 69)**	**(No experimental adjustment)**	**Concept category: Social (S), Living (LN) or Abiotic Nature (AN)**
Fish population health	4.62		LN
Beaver acceptance – Anglers	4.10		S
Public health & wellbeing	3.41		S
Government policy/ finance for nature	3.02		S
Wetland – ecosystem health & services	2.99		LN
Making space for wilder nature	2.42		LN
Holistic enrichment through valuing nature	2.18		S
Natural hydrology – wilder river	1.77		AN
Beaver acceptance – Farmer, landowner, forestry	1.02		S
Beaver presence – (Given) (Clamped as transmitter)	1.00		LN
Public access (Transmitter)	1.00		S
Conflict & distress – natural resource stakeholder (Transmitter)	1.00		S
Science, education & knowledge	0.87		S
Beaver damming and impoundment of water	0.80		AN
Water retention - upper catchment	0.48		AN
Sense of place/ specialness	0.40		S
Flow rate/Problem flooding in lower reaches	0.32		AN
Perception of legal over-protection	−1.81		S

living beaver reintroduction, we identified a predominance of social ‘people-related’ conceptual content in four of five representative key stakeholder mental models. This general observation is important because favourable stakeholder mental model overlap understood as coherent, aligned content and dynamic expectations is thought to be a necessary basis for social cooperation in resilient ecosystems. Numerical predominance of social concepts is consistent with an expectation that human interactions remain central to the detail of people’s concerns, and that social components of mental models are likely to be key to wildlife outcomes.

Compared to nature concepts, ROBT mental model social concepts showed greater content variation across the stakeholder community. Modelling removal of ‘NGO (conservation) leadership’ and ‘Monitoring and mitigation’ reveals increasingly divergent expectations in their absence, with conflict-risk represented by lost farming business viability, more beaver persecution and lower beaver acceptance. This approach is a relatively straightforward and efficient means of retrospectively checking the effects of policy and practice, and we argue underlines how farm payment reform in the U.K. and similar economies might helpfully support leadership and mitigation designed to improve human-beaver ecosystem resilience.

We recommend that mental model analysis by concept removal is an informative additional research method and pragmatic conservation tool in the comparative study of stakeholder mental models, and an original extension to the existing mental model and FCM conservation research repertoire. We also believe that there is scope for developing a wider understanding of the role of mental models in conservation psychology, based on values, attitudes and belief analysis. Our approach to FCM analysis building on mental modelling approaches previously outlined (Jones et al., 2011) and reviewed (Moon et al., 2019), is likely to apply particularly where ambitious wildlife conservation projects are conducted in complex cultural and multiple use environments.

Ethical approval

This research project was approved in writing by the relevant ethics committee at Wageningen University & Research.

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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.

Appendix

See Table 2.

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