The perceptions of stakeholders on current management of mangroves in the Sine-Saloum Delta, Senegal

Manjula Arumugam [a,b,*,1], Richard Niyomugabo [a,b,1], Farid Dahdouh-Guebas [a,b,2], Jean Hugé [a,b,c,d,2]

[a] *Vrije Universiteit Brussels (VUB), Pleinlaan 2, 1050, Brussels, Belgium*
[b] *Université Libre de Bruxelles (ULB), CPi 264/1, Avenue F.D. Roosevelt 50, 1050, Brussels, Belgium*
[c] *Open University of the Netherlands, Valkenburgerweg 177, 6419, AT Heerlen, the Netherlands*
[d] *Centre for Environmental Science, Hasselt University, Martelarenlaan 42, 3500, Hasselt, Belgium*

ABSTRACT

Despite their ecological and economic importance, mangroves have suffered degradation in West-Africa, mostly from anthropogenic activities. To sustainably and successfully manage natural resources in complex social-ecological systems (SES), it is important to take into consideration the divergent viewpoints, values, and knowledge of stakeholders, this allows to make informed decisions by identifying shared views and contentious grounds. We applied Q methodology to identify the subjective perceptions of local stakeholders on mangrove management in the Sokone and Toubacouta regions of the Sine-Saloum Delta in Senegal. Three distinct discourses (distinct viewpoints) were identified following the application of Q methodology: (i) the 'Official' discourse: "Mangrove management is fragmented; communities need to fill in the gaps for the management to work uniformly in all parts"; (ii) the 'Happy Villagers' discourse: "Village-level co-management works but some imbalances need to be corrected"; and (iii) the 'Unhappy Villagers' discourse: "Mangrove management is not working; things need to change, but it is not up to us (the villagers) to act". There is polarization among the discourses on the effectiveness of current management. There is consensus among the discourses in wanting improvements in the current management but there is no agreement on what needs to change. The study highlights the importance of establishing clear guidelines concerning the role of government and other actors in participatory decentralized resource management. The identified areas of consensus can help create opportunities for sustainable management interventions and dissensus viewpoints highlight critical topics that require further discussion to improve the present management regime.

1. Introduction

Mangrove forests provide a multitude of benefits and services, from the provision of materials (such as timber and fisheries) to being a regulating influence (such as protection from storm surges and cyclones, and carbon sequestration), in addition to offering cultural and spiritual benefits (Walters et al., 2008; Mukherjee et al., 2014a). Although crucial for supporting local livelihoods, mangrove ecosystems are becoming increasingly threatened all over the world as they are undergoing rapid degradation (Duke et al., 2007; UNEP et al., 2014). This is mainly due to anthropogenic activities such as urban construction, infrastructure development for tourism, conversion for aquaculture and agriculture, overharvesting of mangrove resources, pollution, and human-induced climate change (Alongi, 2002; Dahdouh-Guebas et al., 2002; Mukherjee et al., 2014b).

Global mangrove area was estimated to be 137,600 km^2 in 2010 (Bunting et al., 2018). Africa accounts for 20% of the extent of mangrove in the world (Bunting et al., 2018) of which approximately 12% is present in West-Central Africa, covering approximately 20,142 km^2 (Ajonina et al., 2008). Studies conducted about 15 years ago for mainly a pre-2000 period showed that the rate of global mangrove loss was estimated at 1% per year (Mayaux et al., 2005; FAO, 2007). More recent

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studies covering the post-2000 period indicate that the rate of global mangrove loss continues at a decreased rate of 0.16–0.39% per year (Hamilton and Casey, 2016). Although the rate of global mangrove loss has declined, the future of global mangrove still remains uncertain as new territories of deforestation are opening up, mainly in Southeast Asia and West Africa (Hamilton and Casey, 2016; Friess et al., 2019). The threats to mangroves continue despite global conservation and rehabilitation efforts.

Though there is an ever-increasing amount of scientific literature and knowledge available today, which highlights the extent of the degradation and identifies its main proximate drivers, this alone seems insufficient in curbing the problem of global mangrove loss (Vande Velde et al., 2019). The strategy of solely emphasizing the ecological functions of mangroves also seems inadequate especially, when drivers of natural resource management decisions, such as the divergent viewpoints of stakeholders and their interests, are insufficiently acknowledged (Rose, 2014). The key to mangrove conservation and restoration is a sustainable management regime, in which community involvement is deemed fundamental (Abdullah et al., 2014; Hugé et al., 2016). The social-ecological costs and benefits of various mangrove management regimes differ, and need to be assessed (Van Oudenhoven et al., 2015), especially as there is increasing advocacy to move more towards a decentralized resource management system (Larson and Soto, 2008; Datta et al., 2012).

Decentralization, i.e. the delegation of power from a center to lower decision-making levels, and community co-management, are commonly seen as pathways to improve ecosystem health and promote sustainable management by overcoming problems related to enforcement, transparency, and natural resource management and government (Edmunds and Wollenberg, 2003; Sudtongkong and Webb, 2008; Webb and Shivakoti, 2008). In order for decentralization or community-based management to work effectively, stakeholders need to be involved in decision-making. This requires taking into consideration their values, interests, and opinions (Forrester et al., 2015). Understanding the interests of a diverse range of stakeholders and how and why a resource should be managed in a way that takes their interests into account, can ideally lead to the adoption of a more effective strategy for the conservation and management of mangrove resources (Dryzek, 2005; Mace, 2014; Tallis and Lubchenco, 2014; Hugé et al., 2016).

As the mangrove forests in the region of Sine-Saloum Delta are not managed according to a uniform management regime nor by a single management body (due to the decentralization policy in place), it has become essential to map the divergent viewpoints of the local stakeholders to assess how the people perceive the current management. It is the hypothesis of the authors that this is key to identifying common ground that can help establish a local management regime that is sustainable from a social, ecological, and economic standpoint. The purpose of this study, therefore, is to identify the differences in perceptions among different stakeholder groups in regard to the management of mangrove resources in the region, and to investigate any misinterpretations that exist between them owing to a lack of understanding of and/or involvement in the management process. We utilized a systematic approach (Q methodology) to identify the similarities and differences in viewpoints among various stakeholder groups, in order to facilitate the complex decision-making process (Hugé et al., 2016; Zabala et al., 2018; Vande Velde et al., 2019).

2. Conceptual framework

Conservation and management are multi-dimensional concepts, and the evaluation of their effectiveness requires looking into human subjectivity and inter-subjectivity (Hugé et al., 2016). Local stakeholders' knowledge and values can be combined with scientific knowledge to design and apply effective and sustainable strategies for natural resource management (Edmunds and Wollenberg, 2003; Webb and Shivakoti, 2008; Vande Velde et al., 2019). In order to foster a shared

understanding among stakeholders, it is essential to explore their attitudes and their differing perceptions of current mangrove management (Hoang Hao and Takeda, 2015). Mapping discourses in mangrove management allows us to locate points of connection between the identified discourses (interpreted perspectives on mangrove management and underlying values) and helps us determine the possible consequences of diverging perspectives on future natural resource management (Hugé et al., 2016). If changes are to be proposed to the existing management regime, this is crucial. Explicitly identified common ground can form the basis for concrete steps forward in the management process; analysis of dissensus points can indicate critical areas requiring further conversation (Redpath et al., 2013). While these conversations and collaborations are essential starting points, they do not guarantee sustainable mangrove-management strategies by themselves (Redpath et al., 2013). Collaborative efforts may be superficial or ineffective if conflicts of interest are left untouched, or as stakeholders may sometimes collaborate only to further their individual interests without a deeper commitment to solving the common problem (Bodin, 2017).

Senegal's decentralization policy allocates control of the land and the management of natural resources — including forest resources — to the local communities (region, municipality, and rural community) for all forest areas (including many protected areas) excluding classified forests, national parks, and strict nature reserves. The 1998 Senegal Forest Code adopts a participatory approach that promotes the involvement of the local population and transfers responsibility to local units for the management of forest resources (Diaw, 2006). The management of the forests falling under the authority of a municipality or rural community is carried out by local entities according to a forest management plan prepared by the respective local entities, which is approved and supervised by the Regional Inspectorate. The State plays a major role in law enforcement and budget allocation and also acts as the main supervisory body of the local communities' exercise of authority. The national forest service and the Directorate of National Parks, with the decentralized structures, oversee the protection and management of strict nature reserves and national parks (Diaw, 2006).

The mode of intervention and the management of mangrove forests in Senegal is similar to that of other forest types. In principle, mangrove exploitation is restricted, and logging is prohibited in classified forest areas (biosphere reserves, strict nature reserves, national parks, etc). Where the mangrove forest falls outside of the classified areas permission from the competent local entities is required in order to access mangrove resources such as wood and fisheries (Diaw, 2006). Coastal populations are permitted to exercise their right of avail only to cut the trees to create poles for rebuilding their huts, though the law also allows them to gather forest products such as dead wood, and nuts, fruits and leaves for consumption upon obtaining permission from local authorities. Though the use of mangrove resources is regulated, the regulations often are not adhered to.

3. Methodology

3.1. Description of the study area

The study was conducted in the municipalities of Sokone and Toubacouta, Senegal. Sokone town (encompassing Ndangane village) (13°46′N, 016°28′W) was the main location of the study in the municipality of Sokone. In the municipality of Toubacouta the study was mainly based in Toubacouta village (13°52′N 016°22′W) and the surrounding villages of Badoudou, Soukouta, Limane, Diamaguiene, Diaglé, and Bambougar El-hadji (Diossong). The two municipalities are part of the large mangrove complex of the south-eastern part of the Sine-Saloum Delta. In the areas under study of Sokone and Toubacouta, the mangrove forest area (including the protected area not in the classified category) is managed by the respective municipalities working with the local populace, which is in line with Senegal's policy of decentralization. The protected forest area under the classified category is managed by the

Department of Water and Forest at the municipal level. The Marine Protected Area of Bambcoung in Toubacouta (AMCPB) is managed by the local communities except for certain sections (e.g. the Fathala forest, a classified biosphere reserve included in the MPA of Bamboung) that are directly managed by the government (National Forest Service, the Department of National Parks (DPN)) (Cormier-Salem, 2014).

3.2. Q methodology

Q methodology provides insight into individual subjectivity and inter-subjectivity and combines both qualitative and quantitative research techniques and analysis in a structured manner that is statistically interpretable (Barry and Proops, 1999; Rastogi et al., 2013; Zabala et al., 2018). It is highly recommended in decision-making contexts and it is less subject to biases such as group-think and the dominance effect (Mukherjee et al., 2018). Q methodology gets its strength by combining qualitative interpretation with statistics. It is often used in the fields of social, environmental, and health sciences and is now being increasingly used in natural resource management studies as well (Sandbrook et al., 2011; Watts and Stenner, 2012; Zabala et al., 2017). Q methodology encourages people to identify the issues and topics that are of importance to them, and thus serves to highlight the numerous subjective yet distinct views among stakeholders (Sandbrooks et al., 2011). Q is a powerful methodology which is being increasingly used to map the perspectives of stakeholders and to capture the plurality of viewpoints (Hugé et al., 2016; Zabala and Pascual, 2016; Zabala et al., 2018).

3.3. Data collection

3.3.1. Concourse and Q set design

The first step in Q methodology is the preparation of a concourse, a body of background information on the topic of interest. This is then reduced to a handful of select statements known as the 'Q set'. The concourse in this study was prepared through a literature review and from 'grey literature' — non-governmental organisation (NGO) reports, tourist pamphlets, community reports, etc. The scientific literature research was carried out on Web of Science and Researchgate by using the following keywords: conservation of mangroves; conservation of mangroves in Senegal and Sine-Saloum Delta; management of mangroves; management of mangroves in Sine-Saloum Delta; threats to mangroves; threats to in West Africa. Following this, the concourse was put through a structured filtering process to reduce it to a manageable set of statements, following the method used by Sandbrook et al. (2011) and by Benitez-Capistros et al. (2016). Finally, 55 statements were identified and chosen as the 'Q set' that was subsequently provided to the participants. The concourse was reduced to the final 'Q set' of 55 statements by thematically sorting the statements (such as values, management, threats to mangroves, alternatives), following the qualitative coding approach as outlined by Rose et al. (2018). Statements expressing the same value or viewpoints were summarised into one overarching statement and included in the 'Q set' (Van Exel and De Graaf, 2005; Watts and Stenner, 2012). A pilot test was conducted at ULB's (Université Libre de Bruxelles) laboratory and the statements were modified based on the feedback received.

3.3.2. Selection of participants

The next step is to conduct a stakeholder identification exercise. Typically, Q methodology does not need a large number of participants but rather a diverse group, so they may represent different viewpoints (Benitez-Capistros et al., 2016; Hugé et al., 2016; Zabala et al., 2018). These selected stakeholders (the P-set) are individually asked to rank the 'Q set' statements according to their perspectives and values, and thus produce arrangements of statements that are unique to each participant ('Q sorts'). The different participant rankings or 'Q sorts' are compared with each other and analysed through a correlation matrix in order to

reveal the clusters of like-minded opinions. These factors are then interpreted, and the explanatory discourses are formed by the process of qualitative analysis based on the post-sorting interviews.

For this study we identified 30 stakeholders representing diverse viewpoints, and interviewed them using Q. The Sokone municipality provided the research team with a letter of permission to conduct research in the area, as part of the existing collaboration between the Sokone municipality and Belgian Zemst municipality. The Sokone municipality contributed to stakeholders identification. This study was conducted in agreement with the ULB (Université Libre de Bruxelles) ethical guidelines regarding interviews. Each participant who took part in this study, was informed about the objectives of this study. Anonymous data analysis was guaranteed. Every participant participated voluntarily (some of them sent their consent via emails to the authors and others gave it verbally to the authors (their consent was recorded as part of the Q interview)). In Q, mapping the diversity of opinions is more important than having a representative set of participants per se (Hugé et al., 2016). The stakeholder selection aimed to ensure that a diversity of stakeholders was included representing an array of perceptions. The stakeholders included representatives of different sectors, such as public administration (the Senegalese Agency for Water and Forests (for the Sokone and Toubacouta regions); the Environmental Protection Agency; the Sokone and Toubacouta Department for Tourism/Ecotourism; the Department of Fisheries Control; municipal agents; NGOs; members of JICA (the Japanese International Cooperation Agency), and other developmental agencies. Members of scientific research institutes, as well as grassroots community organizations such as women's associations, fishermen's associations and youth associations, village leaders, and concerned local communities, were also included in the study. Table 1 lists the characteristics of the Q participants involved in this study.

3.3.3. Q sorting

The selected participants were given the 'Q set' of 55 statements (as separate, numbered laminated cards) and were asked to rank the statements on a Likert scale from −3 to +3 on a chart according to their degree of agreement, wherein +3 represented the highest degree of agreement and −3 indicated the lowest degree of agreement. The chart contained a matrix of an almost normal 'forced' distribution produced on it, similar to the procedure carried out by Hugé et al. (2016). This captures the viewpoints and perspectives of the participants well as it forces them to prioritize their views and perceptions (through the statements) relative to each other and to rank them accordingly (Watts and Stenner, 2012). Forced-choice distribution is commonly used in many Q methodology studies (Cuppen et al., 2010; Hugé et al., 2016). Following the Q sorting exercise, post-sorting qualitative interviews were carried out with the participants in order to obtain more clarity on their viewpoints. The interviews serve to develop the narrative that

Table 1
Characteristics of Q participants (Px indicates the participant identification code, used in result).

Category	Number of Q participants (P)
Officials	
Water and Forestry Department (P1, P7, P13, P21, P30)	5
Management of MPAs (P3, P22, P26)	3
Department of Environment (P11, P15, P29)	3
Department of Fisheries and Fishery Control (P10, P12)	2
Non-governmental organizations (NGOs) (P20, P25)	2
Scientists, researchers and consultants (JICA) (P14, P8)	2
Others	
Local leaders/representatives (P6, P16, P23, P28)	4
Fishermen/women (P4, P17, P9)	3
Ecotourism (P2, P27, P24)	3
Women union representatives (P5, P18, P19)	3
Total	**30**

represents the viewpoints, which are coded as factors resulting from the analysis of the Q sorts.

4. Analysis

Data analysis was carried out with R software (R Development Core Team, 2012) using the 'Q method' package (Zabala, 2014). Through Principal Component Analysis using the Kendall rank correlation coefficient (since multivariate normality assumption was not met), a correlation matrix between the Q sorts was obtained by comparing the association of each Q sort with every other Q sort. Based on this matrix of similarities between the Q sorts, the participants who had sorted the statements in a similar pattern were grouped together into the same factor or component by PCA, thus producing a manageable number of factors which represented the different and various viewpoints of the grouped participants. In Q methodology, the number of factors to extract and thus rotate, that highlight the synthesized overall shared views, needs to be determined. The factor extraction can be completed based on a number of traditional criteria used in Q methodology, namely Humphrey's Rule of Extraction (which states that the cross product of the two highest factor loadings should exceed the standard error by twice the value), the Kaiser-Guttman criterion based on eigenvalue, the total potential for variability that can be explained and even be based on interpretability (as provided by Watts and Stenner, 2012). After extracting the decided number of factors and rotating them, it is important to calculate and check the number of participants significantly appearing on the same rotated factor. These participants can be grouped together since they share similar perspectives and their views can be used to develop the narrative for the discourse they represent.

Initially, eight factors were obtained with an eigenvalue (EV) > 1. Finally, we extracted and rotated five factors based on a combination of the traditional criteria explained above, additionally following the recommendation of Watts and Stenner (2012) by retaining one factor per six or seven participants and considering the scree plot of the eigenvalues. Finally, only four factors were retained as different discourses and explained in detail, as only these factors had the minimum of two or more significantly loading participants (at p < 0.01 level,

Table 2
Varimax rotated factor matrix with factor loadings (performed in R studio); (*) indicates a loading Q-sort at p < 0.01, denoting a factor-defining Q sort.

Q sort	Factor 1	Factor 2	Factor 3	Factor 4
P1	0.21	0.55*	−0.1	0.05
P2	0.38	0.35	0.23	−0.03
P3	0.76*	0.18	0.11	0.12
P4	0.04	0.54*	0.33	−0.01
P5	0.2	0.09	0.71*	0.04
P6	0.51	0.3	0.42	0.1
P7	0.14	0.1	0.19	0.50*
P8	0.28	0.11	0.52*	0.32
P10	0.18	0.01	0.31	0.64*
P11	−0.06	0.09	−0.1	0.74*
P12	0.26	0.39	−0.08	0.31
P13	0.39	−0.01	0.45	0.09
P14	0.79*	0.13	0.17	0.04
P15	0.26	0.4	0.28	0.23
P16	0	0.27	0.72*	0.23
P17	0.36	0.28	0.2	0.49
P18	−0.05	0.57*	0.21	0.27
P19	0.21	0.75*	0.12	0.06
P20	−0.07	0.60*	0.11	0.07
P21	0.59*	−0.12	0.11	0.23
P22	0.63*	0.26	0.09	0.16
P23	0.26	0.01	0.3	0.47*
P25	0	0.02	0.15	0.09
P26	0.32	0.27	0.01	0.36
P27	0.32	0.60*	0.23	0.04
P29	0.46	0.4	0.46	0
P30	0.44	0.19	0.38	0.14

threshold value = 2.58 *$1/\sqrt{}$ (number of statements = 55) = ±0.34; Brown, 1980) (Benitez-Capistros et al., 2016; Hugé et al., 2016). Table 2 shows the Q sorts that 'load' significantly on a specific factor (marked by an asterisk ('*'), which epitomizes the extent to which a respondent (an individual Q-sort) is associated with a particular factor. These factor-defining Q sorts exclude confounder loaders who load in more than one single factor. The most commonly used 'Varimax' (orthogonal) rotation was carried out to maximize the variation within the groups (Zabala, 2014). The discourses were made with the help of the post-sorting interviews (Watts and Stenner, 2012) taking into account the Z scores (the weighted averages of the ranks given to each statement by the participants grouped together in a factor) and the factor arrays of each individual statement (shown in Fig. 1).

5. Results

Although initially 30 participants were included in the Q exercise, participants P9, P24, and P28 were left out of the analysis as their ranking and responses were inconsistent. In other words, their ranking, and their arguments (given in the post-sorting interview) were not matching. These participants found the Q sorting exercise difficult to execute; owing to their social and educational background, they had trouble understanding certain key terms. Upon completion of the rotation and extraction process, four factors were retained out of the initial five factors, explaining nearly 46% of the total variance, which is well above the 35–40% range of explained variance suggested by Watts and Stenner (2012). Table 3 illustrates the degree to which the factors are co-related. Although the factors' Z scores are moderately co-related, the Q methodology allows for distinguishing between the factors through an interpretative approach based on the qualitative section. The inter-factor correlation matrix may also indicate that the four factors are alternate representations of a larger discourse (Watts and Stenner, 2012).

5.1. From factor to discourse

The four statistical factors are developed into narrative discourses based on the qualitative information gathered through the interviews, after identifying patterns in the factors based on statement ranks (Watts and Stenner, 2012). The discourse development process also includes looking into distinguishing and significantly differing statements among the factors. The Q set of statements used, with their associated Z-scores for each factor, is presented in Table 4. The characteristics of the significantly loading participants for each factor are provided in Table 5.

5.1.1. Discourse 1 – official discourse – 'current mangrove management is fragmented: government officials are doing a great job, but communities need to bridge the gap for management to work uniformly in all parts'

In total, 13.7% of the variance is explained by Factor 1 (Table 3). There are four participants significantly loading on Factor 1. This could be termed the 'official' discourse. All the participants significantly loading on this factor are formally educated officials involved in mangrove management. They value the mangroves first mainly for carbon storage and climate change mitigation, followed by storm protection, harbouring biodiversity, and the multiple other ecosystem benefits (e.g. timber, fuel wood, fish (nurseries) are also highly valued (S3, S2, S4, S1)). The discourse embodied by Factor 1 carries the idea that for the successful management and restoration of mangrove forests, local communities need to be more involved (S48). They agree that an active management of mangroves is needed to maintain ecosystem functions, goods, and services (S35). Discourse 1 also reflects the idea that the mangrove area is undergoing degradation in the region (S21).

Participants defining Discourse 1 embody the idea that parts of the mangrove area in the region are not managed well. P3 states "*Current management is erratic which only works in parts*". P3 further explains that different parts of the mangroves of Sine-Saloum Delta come under the
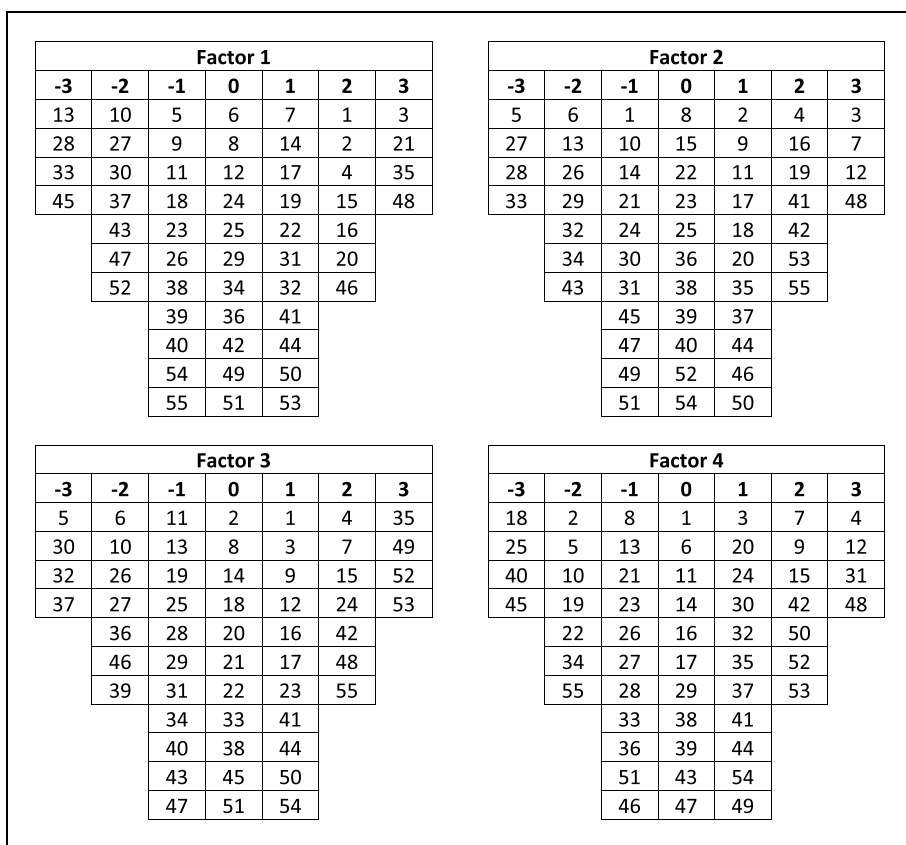
Fig. 1. Contains the ideal-typical Q sort or the so-called factor array for each factor. The factor array appears to be a single complete Q sort as it is a merged average rank of each statement for each factor of the significantly loading participants' Q sorts. The second row from the top constitutes the Likert Scale by which participants were required to rank statements. The statements (represented in numbers) have been sorted under each scale according to their degree of agreement (ranked +1 to +3), disagreement (ranked −1 to −3) or neutrality (ranked 0) for factor 1, 2, 3 and 4 respectively.

Factor 1

-3	-2	-1	0	1	2	3
13	10	5	6	7	1	3
28	27	9	8	14	2	21
33	30	11	12	17	4	35
45	37	18	24	19	15	48
	43	23	25	22	16	
	47	26	29	31	20	
	52	38	34	32	46	
		39	36	41		
		40	42	44		
		54	49	50		
		55	51	53		

Factor 2

-3	-2	-1	0	1	2	3
5	6	1	8	2	4	3
27	13	10	15	9	16	7
28	26	14	22	11	19	12
33	29	21	23	17	41	48
	32	24	25	18	42	
	34	30	36	20	53	
	43	31	38	35	55	
		45	39	37		
		47	40	44		
		49	52	46		
		51	54	50		

Factor 3

-3	-2	-1	0	1	2	3
5	6	11	2	1	4	35
30	10	13	8	3	7	49
32	26	19	14	9	15	52
37	27	25	18	12	24	53
	36	28	20	16	42	
	46	29	21	17	48	
	39	31	22	23	55	
		34	33	41		
		40	38	44		
		43	45	50		
		47	51	54		

Factor 4

-3	-2	-1	0	1	2	3
18	2	8	1	3	7	4
25	5	13	6	20	9	12
40	10	21	11	24	15	31
45	19	23	14	30	42	48
	22	26	16	32	50	
	34	27	17	35	52	
	55	28	29	37	53	
		33	38	41		
		36	39	44		
		51	43	54		
		46	47	49		

Table 3
Factor Z scores correlation, % of variance explained and number of Q sorts loading significantly at p < 0.01.

Z scores	Factor 1	Factor 2	Factor 3	Factor 4	Variance Explained	Number of loading Q sorts
Factor 1	1	0.4929	0.4392	0.3816	13.76	4
Factor 2		1	0.4844	0.3264	12.32	6
Factor 3			1	0.4686	10.61	3
Factor 4				1	8.66	4

management of different municipalities/communes, and sometimes within a municipality some areas are managed by the local municipality while the other areas come under the direct management of the central government. According to P22, "*There is no single uniform process of management for the entire region equally*". P21 elaborates, "*The divisions in the management of mangrove areas across the region due to the decentralization process has led to the conservation and restoration measures to not be uniformly applied in the Sine-Saloum Delta*". P14 states, "*MPA and forest department managements make sure that the mangroves are protected but local village management units do not keep to the same standard*". Since the adherents of Discourse 1 are officials involved in mangrove management and conservation, it is not surprising to see that they support S46, which states "Current mangrove forest management involves protection while ensuring resource access (for local people)," highlighting that it is the case only in the mangrove area they are managing and they believe that this is not the case with the mangrove forest managed by the respective local municipalities.

Most of the participants acknowledge the occurrence of conflict between the local communities and Government officials, e.g. in regard to fishing in a certain area (S45). There is a general opinion that the rules and regulations regarding the use of mangrove resources are not followed well even if they are enforced (S37). As per the input from P6, the conservation effort is limited also because of the different access rules governing private and protected forests, he states "*A man who is fishing in

a restricted area upon being informed of the presence of a Government surveillance officer, moves a few meters away and fishes in the unrestricted area managed by the commune*". P6 calls for a co-ordinated and uniform management between the different mangrove areas while P14 expresses "*Local people, they have to be more responsible and not expect Government to do everything*".

5.1.2. Discourse 2 – happy villagers – 'mangrove management is working thanks to us, but some imbalances need to be corrected'

Factor 2 explains 12.3% of the variance. There are six factor-defining participants associated with this discourse (Table 5). Most of the participants loading on this factor originate from Toubacouta village and the surrounding area. While Discourse 2 also highly stresses the importance of the involvement of local communities for the success of mangrove restoration (S48), the other main opinion governing Discourse 2 is that the mangroves are currently experiencing regrowth and regeneration due to replanting programs, mostly initiated by NGOs (S21, S12). This opinion distinguishes Discourse 2 from Discourse 1. Discourse 2 also embodies the idea that the mangroves are valued not only for the important role they play in the storage of carbon dioxide and mitigating climate change, but also for their function as a nursery for fish and shellfish, and in harbouring unique plants and animals (S3, S7, S4). Discourse 2 emphasizes that the management of mangroves is needed in order to maintain the proper functioning of the ecosystem, as well as

Table 4

List of statements comprising the 'Q set'; Z-scores and ranks for each statement associated with each factor with superscript values representing the significantly differing statements from other factors.

Statements		Factor 1 Z-scores	Factor 2 Z-scores	Factor 3 Z-scores	Factor 4 Z-scores
S1	Mangroves are important because they provide multiple ecosystem services (e.g. timber, fuel wood, fish (nursery)).	1.16[24]	−0.48[13]	0.59[2]	−0.12[1]
S2	Mangroves are most important because they provide protection against floods and storms.	1.38[34]	0.78[34]	−0.14[124]	−1.49[123]
S3	Mangroves are most important because they store carbon/CO_2 and mitigate climate change.	2.12[34]	1.4	0.88[1]	0.81[1]
S4	Mangroves are important because they harbour unique plants and animals.	1.22	1.09	1.16	1.5
S5	Mangroves are important for construction timber.	−0.49[2]	−1.52[1]	−1.32	−0.91
S6	Mangroves are important for fuel wood.	−0.35[2]	−1.17[14]	−1.04	−0.18[2]
S7	Mangroves are important as a nursery for fish and shellfish.	0.53[2]	1.38[1]	1.31	1.04
S8	Mangroves are important for traditional medicinal uses.	0	0.2[4]	0	−0.7[2]
S9	The mangroves have regenerated in the past few years in Sokone/ Toubacouta region.	−0.84[234]	0.59[1]	0.75[1]	1.02[1]
S10	The mangrove area is regenerating due to favourable climatic changes.	−1.17	−0.65	−1.31	−1.32
S11	The mangroves are regenerating due to conservation and management of mangroves.	−0.91[2]	0.72[134]	−0.87[2]	−0.21[2]
S12	The mangroves are regenerating due to replanting programs.	−0.11[24]	1.35[1]	0.72	1.58[1]
S13	Mangrove expansion hinders boat navigation in the bolongs.	−1.43[4]	−1.17[4]	−0.59	−0.31[12]
S14	Shrimp and oyster production are declining in Sokone region.	0.96[24]	−0.83[13]	0.15[2]	−0.18[1]
S15	Fish and shellfish catch in mangrove creeks (bolongs) is declining over the years in Sokone/ Toubacouta.	1.09[2]	−0.09[134]	1.01[2]	1[2]
S16	Sokone/Toubacouta should be developed as a major ecotourism destination.	1.1[4]	0.84[4]	0.86[4]	−0.1[123]
S17	Ecotourism is needed to inform people about mangroves.	0.63	0.79[4]	0.72	−0.02[2]
S18	Ecotourism in Sokone/ Toubacouta mangrove forest creates a lot of jobs.	−0.8[24]	0.63[14]	−0.13[4]	−1.83[123]
S19	Ecotourism allows for fostering mangrove conservation and economic development.	0.84[34]	1.29[34]	−0.31[12]	−1.15[12]
S20	The involvement of local communities is important	1.16[3]	0.82[3]	−0.29[124]	0.69[3]

Table 4 (*continued*)

Statements		Factor 1 Z-scores	Factor 2 Z-scores	Factor 3 Z-scores	Factor 4 Z-scores
	for the success of tourism activities.				
S21	The mangrove area is undergoing degradation.	1.4[234]	−1[1]	−0.16[1]	−0.41[1]
S22	Mangrove degradation is leading to sedimentation of rivers and creeks (bolongs) in Sokone/ Toubacouta.	0.38[4]	0.35[4]	−0.15	−1.02[12]
S23	Mangrove degradation is due to unsustainable exploitation by non-local merchants.	−0.58[3]	0.1	0.44[1]	−0.33
S24	Mangrove degradation is due to cutting down the mangrove trees at the roots in order to harvest oysters.	−0.01[3]	−0.79[3]	1[12]	0.8[12]
S25	Mangrove degradation is due to drought.	0.16[4]	−0.26[4]	−0.72[4]	−2.09[123]
S26	The demand for timber and poles is increasing and causes strong pressure on the mangrove forest.	−0.49	−1.194	−1.18	−0.42
S27	Mangrove degradation is due to salt production.	−1.05	−1.7[4]	−1.14	−0.85[2]
S28	Mangrove degradation is due to charcoal production.	−1.8[34]	−1.86[34]	−0.74[12]	−0.62[12]
S29	Mangrove degradation is due to urbanization.	0.27[2]	−1.5[134]	−0.42[2]	−0.15[2]
S30	Mangrove degradation is due to industrial activities (e.g. fish smoking).	−0.98[4]	−0.72[4]	−1.45[4]	0.49[123]
S31	Mangrove degradation is due to subsistence/ household activities (e.g. fuel wood, construction poles).	0.33[234]	−0.93[14]	−0.89[14]	1.73[123]
S32	Sokone/Toubacouta mangroves prove that exploitation leads to degradation.	0.71[23]	−1.17[14]	−1.32[14]	0.95[23]
S33	Sokone/Toubacouta mangrove is polluted by heavy metals (e.g. Cadmium, Lead) arising from mining activities and industrial effluents.	−1.54[3]	−1.79[34]	−0.28[12]	−0.6[2]
S34	Sokone/Toubacouta mangrove is polluted by small-scale application of insecticides (e.g. DDT).	−0.34	−1.08	−0.85	−1.24
S35	Management of mangroves is needed to maintain ecosystem functions, goods and services.	1.41	0.79	1.59	0.93
S36	Managing Sokone/ Toubacouta mangrove at the village level is effective in conserving mangroves.	−0.38[2]	0.58[134]	−1.3[2]	−0.56[2]
S37	The rules and regulations regarding use of mangrove resources are well followed and enforced.	−1.2[24]	0.71[13]	−1.87[24]	0.31[3]
S38	The resources of the mangroves are sustainably managed	−0.92[2]	0.57[1]	−0.25	−0.01

Table 4 (*continued*)

Statements		Factor 1 Z-scores	Factor 2 Z-scores	Factor 3 Z-scores	Factor 4 Z-scores
	from an economic point of view.				
S39	The resources of the mangroves are sustainably managed from a social point of view.	−0.8[2]	0.38[13]	−1.44[24]	0.04[3]
S40	The resources of the mangroves are sustainably managed from an ecological point of view.	−0.4[4]	0.38[34]	−0.73[2]	−1.6[12]
S41	Conservation of biodiversity (the diversity in plant & animal life) is important in Sokone/Toubacouta mangroves.	0.34[2]	1.3[14]	0.87	0.46[2]
S42	Parts of Sokone/Toubacouta mangrove forest should be kept undisturbed and free of human activity.	0.18[34]	0.97	1.15[1]	1.48[1]
S43	Management should be focusing only on Rhizophora spp., as this is the best tree species to generate timber, poles and fuelwood.	−0.96	−1.32[4]	−0.45	−0.13[2]
S44	The existing strictly restricted and/or total ban on mangrove wood is important for mangrove conservation.	0.94	0.72	0.86	0.86
S45	There are no conflicts between people and government regarding access to land and natural resources (timber, fish, etc.).	−1.69[23]	−0.68[14]	−0.3[14]	−1.6[23]
S46	Current mangrove management forest involves protection while ensuring resource access (for local people).	1.33[34]	0.6[34]	−1.02[12]	−0.86[12]
S47	The shrimp and oyster production industry is well managed in Sokone/Toubacouta.	−1.27[4]	−0.6	−1.01	−0.28[1]
S48	The involvement of local communities is important for the success of mangrove restoration.	1.99	1.9	1.29	1.59
S49	The mangrove restoration projects should be carried out by NGOs working with local people.	−0.34[34]	−0.95[34]	1.9[124]	0.81[123]
S50	The government should be supporting mangrove restoration in Sokone/Toubacouta (e.g. through provision of planting material).	0.82	0.79	0.6	1.12
S51	Sokone/Toubacouta mangrove should be divided in zones with different access rules.	−0.023	−0.453	0.42[4]	−0.88[3]
S52	Replanted mangrove trees should never be harvested.	−1.19[234]	−0.02[134]	1.46[12]	1.48[12]
S53	Creation of (non-mangrove) village woods is an acceptable	0.96[3]	1.18	2.03[1]	1.39

Table 4 (*continued*)

Statements		Factor 1 Z-scores	Factor 2 Z-scores	Factor 3 Z-scores	Factor 4 Z-scores
	substitute for mangrove woods.				
S54	The income generated by afforestation allows the populations to have incomes other than the cutting of wood.	−0.9[34]	−0.34[34]	0.43[12]	0.62[12]
S55	Beekeeping in the mangroves is a key secondary income source in Sokone/Toubacouta.	−0.46[23]	1.08[14]	1.46[14]	−1.05[23]

*Statements significantly differing at $p < 0.01$ level

Table 5
Characteristics of significantly loading participants for each factor.

		Significant loaders
Factor 1		1. Chief of a Forest Department
		2. Conservator of a MPA
		3. Village-level president of a community-managed MPA
		4. Member of JICA (Japan International Cooperation Agency)
Factor 2		1. President of a village women's group
		2. President of a women's economic interest group (apiculture trainer and promoter)
		3. Fisherman
		4. NGO staff
		5. Ecotourism entrepreneur
		6. Local official for the Department of Water and Forest
Factor 3		1. Representative of a women's group for oyster collecting
		2. Local scientist/teacher
		3. Fisherman
Factor 4		1. Local representative of fishery control
		2. Local representative of the Department of the Environment
		3. Local village administrative officer for the Department of Water and Forest
		4. Local village leader

goods and services which are tied to it. Current management should make sure that certain parts of the region's mangrove forest are kept undisturbed and remain free of human activity (S35, S42). It is also stressed that current management needs to focus a bit more on facilitating alternative livelihoods in support of sustainable mangrove management (S55, S53). The importance of ecotourism is understood by all the adherents of Discourse 2. They stress that ecotourism fosters mangrove conservation and economic development, acknowledging that it is growing and creating a number of jobs in the region, but they call for its further development and for further involvement of the local people (S19, S18, S20, S16).

Discourse 2 indicates that the management of mangrove resources is acceptable at the moment, but the participants specify that it needs further improvement and that an inclusive style of management needs to be put in place (S37, S38). P27 expresses, "*Current management assures protection and conservation but does not always guarantee access of mangrove resources for the population in all regions equally*" (S46). P19 states, "*In Toubacouta the local people are involved in replanting and in conservation and in management but not at the base level where the management plan is made*". P22 recommends: "*There are many different initiatives by NGO and local people for managing the resources. The government should group these initiatives and formalize them and include them in the management plan*". In general, there is a shared opinion among the participants that the success of the conservation and management of the mangroves in their region is solely due to the involvement of the local

people. Summing it up, P18 declares, "*It is more villagers doing conservation than government*" (S50).

5.1.3. Discourse 3 – unhappy villagers: 'mangrove management is not working due to a lack of alternatives for the local people'

Factor 3 explains 10.6% of the study variance. It is characterized by three participants being significantly associated with it. The supporters of this discourse are mainly found to be villagers living around Sokone. The focus of this discourse is on the alternatives that the local population find acceptable in order to reduce pressure on the mangroves' resources and to provide support for a diversification of livelihoods. The participants welcome the idea of creating a village forest for fuel-use in substitution of mangrove wood (S53). The female participants confess that they were encouraged to practice apiculture in the mangroves and that they see apiculture as a viable secondary source of income (S55). All the participants accept that the practice of apiculture was not widespread due to the lack of large-scale awareness and training programs. Participants significantly loading on this discourse support NGOs working with the local population to replant mangroves but call on the government and the NGOs to pay the population for carrying out the replanting, which they suggest will motivate the population to replant more and will provide them with an income other than that from the logging of mangrove wood (S49, S50, S54).

Discourse 3 seems to be a more pessimistic variant of discourse 2. Similar to discourse 2, it reflects the desire for an active form of management and highlights the importance of the involvement of the local communities in conservation efforts (S35, S48). Regardless, the participants appear unsatisfied with the current management and level of involvement of the local people (S46). P8 claims that the village-level management of the mangroves is not effective enough when it comes to conservation, and adds, "*People depending on the mangroves have a problem with the current management and the government rules concerning the access to the resources*" (S36, S44). As P8 explains, "*Mangroves have been the main source of livelihood for generations; to not be able to access or use them, is not an option for many villagers*". P16 asserts, "*People are not respecting the rules! But due to lack of surveillance they get away with it*" (S37). The general view is that the current management does not ensure access to mangrove resources for the local communities, and hence leads to illegal exploitation which further leads to conflict between the state authorities and the local communities (S46, S37, S36). P5 reveals, "*There is no particular method of mangrove resource management; there are only restrictions and people disregarding them,*" and according to P16, "*The resources are not well managed from any point of view, whether ecological, social or economic*" (S39, S40). In Discourse 3, the mangroves are valued for their harbouring of animals and plants and acting as nursery grounds for fish and shellfish (S4, S7).

5.1.4. Discourse 4 – unhappy villagers: 'things need to change, but it's not up to us to act'

Factor 4 explains 8.66% of study variance. There are four factor-defining participants associated with this discourse. This discourse can be termed as the 'local/community opinion' discourse as the participants embodying this discourse are people from Sokone. Though Discourse 4 is similar to Discourse 3, it differs in aspects such as the reason provided for the mangrove degradation and for the current failures in mangrove management. The participants focused foremost on the fact that the surrounding mangroves have undergone degradation over the years mainly due to human subsistence/household activities (S31). They strongly deny that it was due to natural causes such as droughts, instead highlighting anthropogenic activities (S25). However, the discourse indicates that due to substantial replantation programs carried out in the region by NGOs with the villagers, the mangroves have been slowly regenerating in the past few years, though many of them felt this was not enough (S12, S9). They put forth that the involvement of the local community is important for the successful restoration of the mangroves, but they felt that the village-level mangrove management

has not been effective (S48, S36). P10 discloses that "*Surveillance is non-existent in many areas and the rules are not well applied by the officers,*" due to which some of the local people access the mangroves illegally (S37, S46). P11 believes, "*NGOs working separately and not with the municipal authorities is not fully effective,*" and stresses that the local people need to be consulted more on management and conservation decisions (S35, S48).

According to P23 "*The government needs to be more involved and supportive in replantation and conservation processes,*" which the other participants agreed with (S50). There is a general consensus among the participants in this group that the resources of the mangroves are not well managed, especially from an ecological point of view (S40). S42, which calls for a section of the mangrove to be kept undisturbed and free of human activity, is highly supported by the participants and many of the participants also feel that the replanted mangroves should never be cut or used (S52). But at the same time, they oppose the idea of zonation which would subdivide the mangrove forest into zones with different rules (S51). P10 insists, "*Even the other parts of the mangrove forest need to be equally protected and that is only possible with the government collaborating with the villagers*". In Discourse 4, the mangroves are valued most for harbouring animals and plants, and not valued at all for the role they play in providing protection from floods and storms (S4, S2). There is a uniform agreement that ecotourism is not well developed in the area yet, that as such it has not created many jobs yet, and hence it is not seen as a contributing factor to economic development (S17, S18, S19).

5.1.5. Discourse 3 and 4: 'unhappy villagers'

Discourses 3 and 4 can be grouped together into one larger discourse that indicates that the participants feel the current management does not encourage conservation while ensuring access to the natural resources for local people (S46). The strong opinion that exists is that the current village-level management is not fully effective as the rules and regulations are neither applied well nor followed properly (S36, S37), leading to a conflict between state officials and the local populace (S45). The other main idea governing these discourses is that the current management is failing due to the lack of alternatives and because the government is not playing a large enough role resource-wise (S53, S52, S46). The main focus is on asking for acceptable alternatives and including the local communities in the decision-making processes regarding management (as P11 opines, "*The village action group has to have more power*").

5.1.6. Consensus among participants

Statements 4 and 44 are consensus statements that do not distinguish between any pair of factors at $p > 0.01$, which includes valuing the importance of the mangrove forest because it harbours unique plants and animals and evaluating the existing ban on mangrove wood logging. The participants exhibit positive stances on both of these statements. Statement S4 is consistently ranked between +2 and +3, while S44 is ranked between 0 and +1. Statement 48 (the importance of the local community in mangrove restoration) was consistently ranked positively between +2 and +3. Negative values (−1 and −2) were granted to S10 (mangrove regeneration due to favourable climatic conditions). Due to the fact that there are no industries or salt production in the immediate area, the participants believe there are no threats to the mangroves due to this (S27, S28, S33, S34).

6. Discussion

6.1. Diverging viewpoints

Like the results of the previous studies concerning environmental resource management (Lansing, 2013; Rastogi et al., 2013), there is polarization among the identified discourses. Discourse 1, being the discourse coming from officials involved at the department level, takes a more defensive stance that embodies the idea that '*we are doing a good*

job because of which management processes we are involved in are working, but the local people need to do their part in their respective regions for the management to work at the community-level'. This 'official discourse' also hints at stimulating the local population to take up further responsibilities and insinuates that the local people should not expect the government to do everything. Discourse 2 carries the opinion of the villagers aimed only at their neighbourhood (local level management). This 'happy villagers' discourse arises from the Toubacouta municipality where there is a marine protected area that was created and is managed by the community. This discourse credits the involvement of the local people as the sole reason for the satisfactory management process. They believe that it is '*all thanks to us, not the government*'. The advocates of this discourse accentuate that they are happy with the local village-level mangrove management but need a few remedial changes. However, Discourses 3 and 4 ask the State/government to further involve the local inhabitants and to provide them with a bigger role in the management process, insinuating that the current management is not working to the best of its ability. The adherents of these two discourses expect a bigger role from the government in the form of resources and opine that the government should do a better job at conserving the mangroves. This is interesting in light of the fact that group participants in Discourses 3 and 4 are stakeholders from the same municipality; according to the decentralization policy, they and their municipality should normally be implicated in management of the mangroves' resources.

The differing perceptions identified in this study imply a 'community vs. government' situation, with most of the discourses hinting at wanting a change in the current management process. This was not the case in the mangroves of Matang, Malaysia, where there was consensus among governmental and non-governmental stakeholders regarding the effectiveness of the current management. There, the management was clearly focused on the labour-intensive and relatively profitable organized timber and charcoal production, in a well-organized entrepreneurial setup with clearly defined roles, responsibilities, and benefit-sharing (Hugé et al., 2016). Decentralization as observed in this study in Senegal, however, appears poorly executed: responsibilities seem to be simply transferred over to local units, which may be more accountable to the central government rather than to the local communities (Ribot, 1999; Lindsay, 1999) — perhaps leading to the divergence of perspectives observed in this study. In some cases, the local units also lack the capacity to effectively manage natural resources (due to insufficient funds, staff shortage, etc.). This 'community vs. government' paradigm observed in the discourses, is visible and discussed in many cases concerning natural resource management around the globe (Fisher et al., 2007; Larson et al., 2010; Baynes et al., 2015).

6.2. Decentralization — A double-edged sword

The perceptions indicating uneven management could be the result of a decentralized resource management process lacking a proper foundation. Despite far-reaching advocacy on behalf of decentralization, which supports the concepts of participatory process and community management, it is often the case with such efforts that the community faces a state of insecurity and legal uncertainty (Bruce, 1999) while lacking the knowledge of where the role of the government ends. This ambiguity can create confusion for both the management of and conservation process for mangrove resources. This can further result in one entity expecting the other to make a better effort, or in some cases one entity blaming the other, which can lead to setbacks in such endeavours. There is an indication of this scenario in this study, where the government officials and community stakeholders seem to have different expectations of each other regarding mangrove management responsibilities. There needs to be more clarity when it comes to communication and arrangements between the neighbouring communities and the government, to obtain a more uniform and effective region-wide management (Hoang Hao and Takeda, 2015). A similar situation of unclear, ambiguous division of responsibilities in the

management process due to decentralization is seen in many African countries including Uganda and Kenya (Ribot, 2002; Oosterveer and Van Vliet, 2010).

Even though all the people who were consulted, including officials at various levels of management, called for greater involvement of the local communities, their statements over how this should be carried out often conflicted. While the officials pointed out that the locals should have to take up the responsibility of conserving the mangroves and other natural resources on their own, the villagers demanded that the government include them more during the planning stage. The local communities expect the government to do more for them, with this support taking different forms, such as provision of resources, paying the locals to do the replanting, and providing more guards to watch over the protected areas.

6.3. Ecosystem service diversification and increasing livelihood options

The importance of diversifying local livelihood options to curb dependency on natural resources has been recommended in various studies globally (Dahdouh-Guebas et al., 2000; Zorini et al., 2004; Datta, 2017). In this study too, opinions concerning alternatives and livelihood diversification occupy center stage. All stakeholders welcome the idea of alternative natural resources in place of mangrove resources, such as a village forest to meet local wood demands, and the promotion of alternative livelihood options like agriculture and apiculture. The stakeholders' willingness to lower their dependency on mangroves for wood (S5, S6, S26) is also in line with the study's finding that mangroves are valued more for their ecological functions such as harbouring unique plants and animals and storing carbon (S3, S4, S5) than for providing goods such as timber and fuelwood (S5, S6). This is surprising in that it is contrary to the findings of Hugé et al. (2016), where the utilitarian value of mangrove resources for humans dominates over their intrinsic value in nature. This could be the result of many awareness programmes conducted in the region highlighting the ecological importance of mangroves.

In the Sine-Saloum Delta mangroves, many recent statements and actions of the local communities demonstrate their interest in conserving the mangroves; however, difficulties with the current hierarchy of management, and a lack of communication between the village and national governmental levels hamper this willingness. While the future results of the current conservation policies and activities remain to be seen, the opinions presented by the consulted locals illustrate a promising basis for the conservation and sustainable management of mangroves in the future.

7. Conclusion

The application of Q methodology in this study revealed three distinct perceptions of the stakeholders on current management of mangroves in the region: 'mangrove management is fragmented'; 'mangrove management works but some imbalances need to be corrected'; and 'mangrove management is not working and things need to change'. The discourses exhibit commonality in wanting improvement in current management but there is no agreement on what needs to change or in what direction. Awareness of these stakeholder perspectives can form the basis for analyses of the situation and conversations on the way forward. As assessed in this study, in the context of decentralization there are some benefits, such as implicating local people or increased mangrove regeneration, but also definite drawbacks and consequences. These have included the pitfalls related to a fragmented chain of management, a lack of communication between different levels of this management, as well as other issues related to the organisation of activities and conservation at the village level. As a pathway to achieve better management while also garnering support for conservation, it might be important to bestow a degree of autonomy upon the community to manage their resources, with clear guidelines as well as well-

defined benefit-sharing mechanisms under the able supervision of the local government entity. The notion of many African countries (e.g. Uganda, Ethiopia) choosing decentralization is encouraging vis-a-vis including the community in the decision-making process; yet, in practice, it does not seem to work perfectly (at least not yet). The current mangrove management approach in Senegal could stand as an example of 'good on paper but tricky in practice'. Q methodology has permitted us to identify existing issues and consensus among stakeholders regarding current management, which can be considered a good beginning for policy debates. Based on the identified consensus and dissensus topics, stakeholders from the different municipalities can collaborate to achieve common goals for successful management at least at the local level. The identified discourses need to be explored in the context of future policy in the region as well as in Africa as a whole. Identifying and acknowledging diverse viewpoints of stakeholders can help develop resilient approaches towards natural resource management globally.

Declaration of competing interest

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

CRediT authorship contribution statement

Manjula Arumugam: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft. **Richard Niyomugabo:** Resources. **Farid Dahdouh-Guebas:** Conceptualization, Methodology, Supervision, Writing - review & editing, Project administration, Funding acquisition. **Jean Hugé:** Conceptualization, Methodology, Supervision, Writing - review & editing, Project administration, Funding acquisition.

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Appendix A. Supplementary data

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