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Murky water: Analyzing risk perception and stakeholder vulnerability related to sewage impacts in mangroves of East Africa

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ABSTRACT

Coastal cities in East Africa are growing rapidly and consequently there is a rapid increase in urban sewage production, putting added pressure on already strained treatment systems. As a result, peri-urban mangroves are receiving extensive amounts of sewage but very little is know as to the ecological and societal consequences of this. However, UNEP among others advocate the use of low-cost, natural sewage treatment technology whenever possible and mangroves have been suggested as useful second stage biofilters. Because of the high resource dependency in many peri-urban coastal communities in East Africa, it is imperative to investigate potential societal impacts on local communities using sewage impacted peri-urban mangroves. Consequently this paper aims to characterize stakeholder groups currently affected by sewage impacted mangroves and thus also map vulnerabilities across local users in relation to future initiatives to use mangroves as biofilters along the East African coast. As risk perception is an important part of vulnerability, and risk perception related to sewage and pollution in an African setting has been little studied, we also aim to contribute baseline data on risk perception related to pollution across peri-urban populations in Kenya, Tanzania and Mozambique.

1. Introduction

Coastal areas of the developing world are often extensively populated and in many tropical regions peri-urban population concentrations also coincide with the existence of mangrove ecosystems. Consequently, many fringing urban communities depend heavily on mangroves for both subsistence and commercial harvesting of products (MA, 2005; Rönnback et al., 2007). Coastal cities in East Africa are growing rapidly (ICLARM, 1999; Mohammed, 2002; UNEP, 1998) and as a consequence there is a rapid increase in urban wastewater production, putting added pressure on already strained treatment systems. According to da Maia (1999) and UNEP–GPA (2000) the sewage system of Dar es Salaam, Mombasa and Maputo serve only 15%, 17% and 10% of their respective populations. As a result, peri-urban mangroves are receiving an extensive amount of sewage but very little is know as to the ecological and societal consequences of this (Adeel and Pomeroy, 2002; Holguin et al., 2001).

The biofiltering function of natural mangroves limits coastal sewage pollution to some extent. However, sewage effluents are also likely to affect other ecosystem services. Increased nutrients will enhance tree growth but pathogens and heavy metals are a potential health hazard for people exposed through use of mangrove resources or consumption of mangrove associated marine products. The filtering service of mangroves have nonetheless been put forth as one sewage management option whereby mangroves are strategically reforested or conserved for biofiltration. Since few developing nations can afford immediate investment in sewage infrastructure UNEP/GPA (The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities) advocate the use of low-cost, natural sewage treatment technology whenever possible (UNEP–GPA, 2000). Constructed wetland technology (phytoremediation) is an example of this. The technique uses an enclosed wetland area, planted for the purpose, to 'naturally purify' controlled emissions of

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primary or secondary treated wastewater. Constructed wetlands are attractive to developing countries due to their low cost, easy operation and low technology (Corredor and Morell, 1994; Kivaisi, 2001; von Sperling et al., 2001), but the existing know-how originates predominantly from temperate regions and may not be transferable to the tropics (Kivaisi, 2001).

In light of the growing demand for low-cost sewage treatment along the East African coast, EU recently funded an effort to study the use of strategic re(af)-forestation of mangroves for use as second stage sewage filters (PUMPSEA, INCO-CT2004-510863). This paper stems from data collected as part of a Social Impact Assessment of such initiatives on local, adjacent communities in three countries across east Africa. It is well known that mangroves have a high capacity for filtering suspended and particulate matter (Hemminga et al., 1994) and that mangrove sediments make efficient 'sinks' of nutrients (Alongi, 1990, 1991, 1996; Boto et al., 1989; Hemminga et al., 1994; Holmboe et al., 2001; Rivera-Monroy et al., 1995) but it is uncertain how this capacity will translate to efficiently filter sewage. In addition, understanding of the capacity of mangroves to filter pollutants, particularly pathogens, is based on very limited work and very little attention has been paid to domestic sewage (Clark, 1998). Because of the high resource dependency in many peri-urban coastal communities in East Africa, it is imperative to investigate potential societal impacts of using mangrove areas for sewage treatment. Effects of sewage and sewage related pathogens on human health has been looked at in terms of infectious disease spread (e.g. Louis et al., 2003; Olago et al., 2007; Rogers, 1996; Singh et al., 2004) as well as use of sewage sludge and water for irrigation of crops (e.g. Rogers, 1996; Singh et al., 2004), but to our knowledge societal and cultural impacts on communities affected by sewage effluent in mangroves have not been previously studied. Consequently this paper aims to map vulnerabilities across local users in relation to sewage pollution in mangroves along the East African coast. Vulnerability is here seen as comprised of both physical exposure, potential loss of livelihood and perception of risk associated with the exposure.

Vulnerability is a large and diverse field of inquiry. We will therefore begin by putting the present study in the context of existing vulnerability research and discuss how it relates to the field of risk perception. A majority of risk perception work has been conducted in western countries. Risk perception literature in an African context has dealt largely with AIDS (e.g. Cleland and Ferry, 1995; Stringer et al., 2004), or risks associated with farming or pastoralist communities in semi-arid regions (Hardaker et al., 1997; Smith et al., 2000, 2001). To our knowledge few studies have looked at risk perception related to sewage and pollution in an African setting. As such this study also aims to contribute baseline data on risk perception related to pollution across peri-urban populations in Kenya, Tanzania and Mozambique.

2. Vulnerability and risk perception—definitions and conceptual frameworks

Many different disciplines make use of the term vulnerability, ranging from psychology to engineering, anthropology and economics. The exact meaning of the term is contested, particularly in fields studying the interaction between humans and their environment. For comprehensive reviews of vulnerability research and its antecedents (see, e.g. Adger, 2006; Smit and Wandel, 2006; Cutter, 1996; Cutter et al., 2003). However, some commonalities can be discerned in terms of how vulnerability is conceptualized in the context of social-ecological systems. For example, it is widely recognized that a system's vulnerability is a function of the *sensitivity* and *exposure* of the system to some external, hazardous condition, as well as the capacity to adapt (Adger, 2006; Smit and Wandel, 2006). One of the influences on contemporary vulnerability research, as outlined by Adger (2006), has been research focusing on vulnerability as absence of entitlements, i.e. sensitivity of a population. This has also given rise to an independent strand of research focusing on sustainable livelihoods and vulnerability to poverty. This idea of vulnerability as a lack of access to essential resources is in this study captured by how sensitive to exclusion from the mangrove resource respondents perceive themselves to be, and it is elaborated upon in the conceptual framework presented below. Other strands of research, including that of natural hazards and pressure and release (PAR), have also contributed to the concept of vulnerability in social-ecological systems. Burton et al. (1993) review and summarize how such external hazards affect populations in different ways. Along with other scholars they show that natural and technological hazards tend to differ significantly in how they affect different groups in society, as a function of varying degrees of exposure and capacity to adapt (Burton et al., 1993; Smith et al., 2001). In his review, Adger (2006) calls for the development of a generalized measure of vulnerability, building on both sustainable livelihoods and hazards traditions. Drawing on the literature from both fields of vulnerability and risk assessment, this study thus defines vulnerability as being comprised of the following components; exposure to hazard and sensitivity to exclusion from a valuable resource. We also include perceived risk as an element which affects vulnerability. How these components come together conceptually to describe vulnerability in our case is discussed in greater detail in the next section. We also acknowledge that our attempt at constructing a vulnerability index related to sewage impacts for communities surrounding impacted mangroves is not completely comprehensive. This is particularly true with respect to health impacts which are also affected by behaviours and capacities relating to work practices, protective measures such as hygiene, consumption of contaminated products, and on factors such as health status, to mention a few.

On the flip-side of the vulnerability coin we find risk. Risk and uncertainty is, like vulnerability, a vastly researched field. It has been reviewed at length in relation to agriculture and livelihoods by Hardaker et al. (1997). While running the risk of oversimplification one can nonetheless, as suggested by Smith et al. (2000), identify two broad approaches to the study of risk as it relates to vulnerability. One is how potentially affected individuals perceive the threat at hand. This allows for assessing variation of risk among subjects identical in all other respects (such as age, gender, occupation, proximity to source of disturbance, etc.). The other approach is based on measurements of some directly observable hazardous variable affecting a population, and is usually measured in terms of frequency of occurrence. Vulnerability scholars have similarly acknowledge this dual nature (direct and perceived vulnerability), and the need to include both aspects when attempting to measure differential vulnerability among populations (Adger, 2006). This thus motivates the inclusion of risk perception in our index.

Various definitions of risk and risk perception are found in different disciplines but there is a consensus about the socially constructed nature of risk which mandates an understanding of risk perception. While psychometric research has focused more on perception of risk in relation to modes of cognition and personality (Slovic, 1987; Slovic et al., 1982), others have emphasized the role of social context and cultural processes in shaping our beliefs about hazards (Beck, 1992, e.g. Douglas and Wildavsky, 1982). Research on perceptions of environmental risk has also shown that local context and experience plays a strong role in defining perceptions of environmental risk (Bickerstaff and Walker, 2001; Irwin et al., 1999; Macgill, 1987).

In this study we choose to adhere to the definition of risk proposed by Smith et al. (2000) and Hardaker et al. (1997) and hazard will be used synonymously with risk. By risk we thus mean certain consequences, particularly exposure to potentially unfavourable circumstances, or the possibility of incurring non-trivial loss. As Smith et al. (2000) point out, this distinguishes risk from uncertainty, which reflects imperfect knowledge without any value assessment of the consequences.

The factors which affect how people perceive risk, have, like the concept of risk and risk perception themselves, been largely contested. Factors affecting general risk perception, and perceived health risks, include the probability of harm perceived by individuals, the level of knowledge a subject has about the hazard, and the ability to control or mitigate the risk (Weinstein, 1999), as well as the value of the resource at risk (Blomkvist, 1987). For public risk perception of pollution and environmental hazards factors believed to influence are the nature of pollution (Wall, 1973; Zeidner and Shechter, 1988) and the level and nature of publicity around it (Auliciems and Burton, 1971; Slovic, 1987). Cognitive science has identified systematic biases in people's estimation of risk. Systematic underestimation of risk has been empirically shown to exist (Weinstein, 1980, 1982, 1984), and to potentially affect behaviour (Janz and Becker, 1984) particularly within the field of health psychology. Subjects tend to systematically underestimate their own vulnerability, both in relation to others and in absolute terms, a phenomenon referred to as unrealistic optimism (Weinstein, 1980, see also Wenglert and Rosén, 2000 for review). Similar results have also been seen in studies of perceived threats from environmental hazards, where respondents, while recognizing the existence of pollution, tend to down play potential negative effects of this pollution on their own health or well-being (Bickerstaff and Walker, 2001). With a few exceptions (Lek and Bishop, 1995), most studies on unrealistic optimism have been conducted in Western countries. Thus little is know as to how cross-culturally valid the concept is. Although this study does not explicitly set out to measure the risk perception biases of respondents, it provides some baseline data on how individuals in peri-urban environments in East Africa think about pollution and threats to their own health as well as to that of the environment.

2.1. Conceptual framework for vulnerability analysis

The framework used to categorize respondents vulnerability draws on the vulnerability and risk perception and assessment literature, incorporating exposure, risk perception and sensitivity. Perceived risk in relation to a hazard, is an important determinant of vulnerability, reflecting an individual's belief that he or she may be exposed to a certain hazard. Exposure is therefore commonly conceptualized as comprising both direct physical contact with the source of potential contamination and the perceived risk of contamination (Adger, 2006). We follow this approach and outline how each vulnerability component was assessed below.

2.1.1. Exposure

Direct exposure is measured by how often respondents currently visit the mangroves. The communities sampled in this study all make use of sewage impacted mangroves, hence this proxy is a good indicator of direct exposure to the hazard of sewage contamination. It is important to note, however, that this approach does not capture exposure through consumption, which is an equally important part related to health risks, and we acknowledge this flaw as also mentioned above.

2.1.2. Risk perception

Perception of risk is a compound measure arrived at by summarizing respondents' responses to the following questions: How do you define pollution? What harmful, if any, component(s) does sewage carry? Are you aware of sewage pollution in the mangrove forest or in the surrounding waters? How does sewage affect you? Responses were assigned values such that a high score indicated low perception of risk associated with sewage exposure, while a low score indicated a high perception of risk (see Appendix A for rank scores). This approach attempts to capture the diversity with which respondents perceive risk, and also allows for an analysis of how respondents recognize risk at a general level, and how this is linked to perceptions of specific risk to their own well-being (see, e.g. Bickerstaff and Walker, 2001).

2.1.3. Sensitivity

Perceived exclusion from a valued resource is a measure of sensitivity to loss of livelihood and is based on respondents' responses to questions regarding the effects, for themselves or others, if mangroves were (i) severely degraded, (ii) lost, or (iii) became inaccessible, as well as number of alternative incomes and whether respondents harvest subsistence products from mangroves. This compound measure indicates respondents' perceived vulnerability to exclusion and impeded access to the mangrove resource and is a proxy measure for mangrove resource dependency (see Appendix A for rank scores). Responses were assigned values such that a high score indicated that respondents did perceive exclusion as having a likely negative effect on their livelihood, while a low score was assigned respondents who did not feel their livelihood would be significantly affected.

The vulnerability categories (High, Medium or Low) are based on different combinations of the vulnerability components (exposure, risk perception and sensitivity), as illustrated in Fig. 1. Thus, which vulnerability category a respondent falls into is a function of the specific combination of these components. Such a disaggregated approach in assessing exposure, risk perception, and sensitivity allows us to generate a vulnerability index based on a combination of scores which in turn is based on social context (Smith et al., 2000).

3. Methodology

Semi-structured interviews were conducted with 136 local users in coastal areas impacted by sewage in Kenya, mainland Tanzania, Zanzibar and Mozambique ($n = 30$, $n = 61$, $n = 15$, $n = 30$, respectively). The use of a standardized questionnaire enabled comparisons within as well as between countries. However, note that because the lower number of respondents in Zanzibar comparisons including this site should be made with caution. The questionnaire was structured around several themes including: personal information/demographics; knowledge of mangroves, threats and (re)plantations; mangrove goods and services; pollution. Questions were asked in increasing order of specificity and open ended responses were recorded so as to not constrain responses and to allow a more nuanced array of responses. This was particularly important to understand how respondents define and think about pollution and risks related to it. Open ended responses were later coded (see Section 3.2). All interviews were conducted in the native language of respondents. All respondents in Kenya, Tanzania and Zanzibar were Kiswahili speakers, while respondents in Mozambique spoke Portuguese.

We used semi-purposive sampling in which local communities currently using mangroves impacted by sewage were targeted, and stratified sampling was done across user groups defined à priori as corresponding to occupation. Within each occupation respondents were approached as randomly as possible either in their home (if respondents occupation was known beforehand) or while carrying out their occupation. Many occupations are gender specific, hence gender was strongly correlated with occupation. In addition, some occupations did not exist in all sites. Data were collected between September 2006 and January 2007. All respondents where inhabitants of local communities adjacent to impacted mangroves and the study does not include any commercial interests.

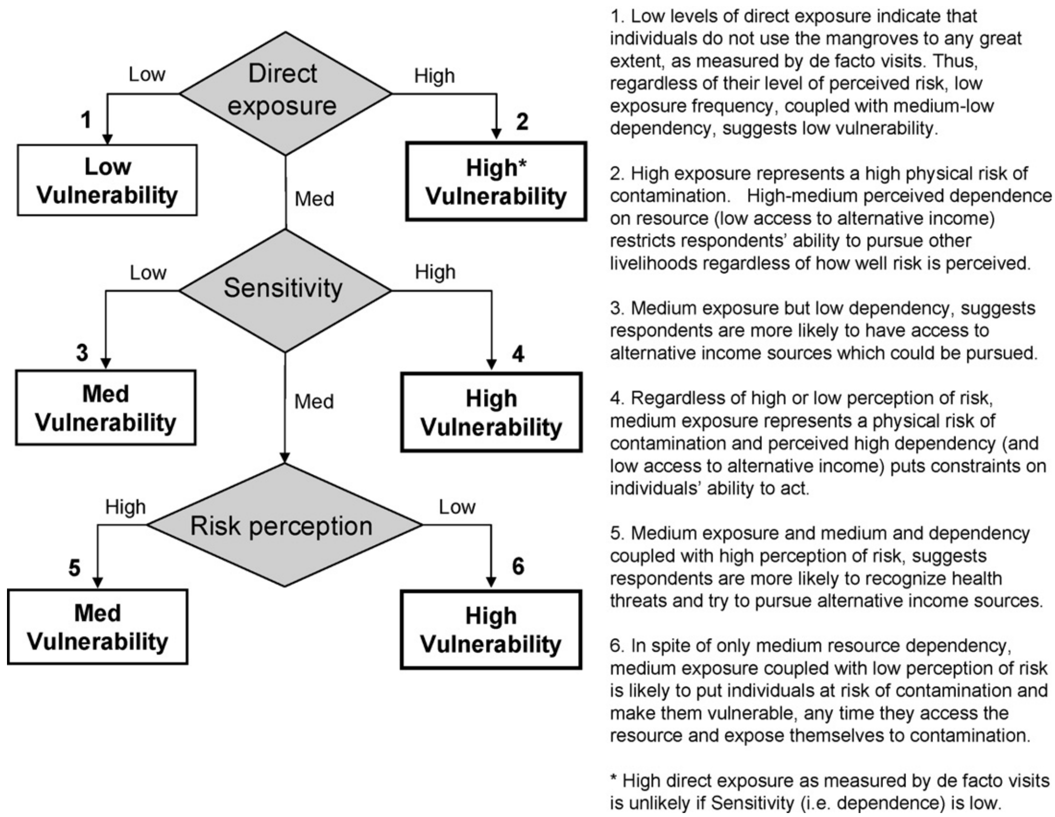

Fig. 1. Conceptual framework for vulnerability analysis. This is a form of decision tree. It is based on the assumptions that (1) direct exposure is the most powerful measurement at our disposal of de facto use of impacted mangroves, and hence risk of contamination, and (2) perceived dependence on the resource for sustained livelihood constrains choices despite potentially perceived risks. Therefore, risk perception is always present in each vulnerability categorization step but due to these assumptions is it over-ridden in cases where direct exposure is H or L, and where resource dependence (Sensitivity) is H or L. Consequently it appears to arrive later in the decision making tree hierarchy.

3.1. Site descriptions

Four communities within peri-urban areas, close to the largest coastal urban centre in each of the three countries, were surveyed: Costa do Sol (Maputo, Mozambique), Mikindani (Mombasa, Kenya), Kunduchi Pwani (Dar es Salaam, Tanzania), and Maruhubi/Maruhubi villages (Zanzibar Town, Zanzibar/Tanzania) (Fig. 2). The estimated population of surveyed areas (based on most recent census data available from each country) varies from Maruhubi/Maruhubi villages (8,212, 2002 census), to Costa do Sol (14,186, 1997 census), and Mikindani (32,485, 2001 census). Only aggregated figures for Kunduchi Ward (in which Kunduchi Pwani village is located) were available (72,927, 2002 census). However, census figures represent large areas in which sub-communities exist and continuously expand without clear boundaries. Such fringing communities, in close proximity to mangroves were targeted here. In all communities inhabitants are involved in extraction of forest or marine products in, or in close vicinity of, the adjacent mangroves although what products, and to what extent, is determined partly by cultural and economic preferences. All surveyed communities were located close to mangroves with known sewage discharge.

3.2. Analysis

Responses were coded in two stages. Firstly into a qualitative code which was subsequently converted into a quantitative score for the vulnerability analysis (see Appendix A). Scores were assigned so that higher values represented a potentially higher vulnerability (e.g. a high score for perception of risk means the respondent has a low perception of risks associated with pollution and sewage and is therefore potentially more vulnerable). For each respondent, rank codes were summed for each of the aggregate measurements to arrive at a final score for each of the vulnerability components, i.e. direct exposure, perception of risk, and perceived exclusion from the resource and respondents' vulnerability was categorized according to Fig. 1. The values for cut-off points between High, Medium and Low for each of the components are listed in Appendix B.

The distribution of respondents across each vulnerability category (High, Medium, Low) in terms of gender, occupation and country, was tested using χ^2-test, to determine if representation within each category differed significantly from what could be expected by random distribution. Because some expected cell counts were small, simulated *p*-values based on Monte Carlo simulations (50,000 replicates) in *R* are reported here. These did not differ significantly from Pearson's *p*-values.

Multivariate analysis was used to explore similarities between respondents, based on responses within the Exposure, Risk Perception and Sensitivity categories using the qualitative codes. Principal Component Analysis (PCA) was calculated based on qualitatively coded answers, each treated as one variable. These were analyzed in conjunction with analysis of the contribution of each variable to average resemblances between sample groups (SIMPER). This helps to assess which responses contribute to the clustering of respondents in multivariate space. Multivariate analysis was run with Canoco 4.5 and Primer 6.0.

4. Results

4.1. Characterization of main stakeholder groups

The total sample included 65% men. Fishermen represented by far the largest occupational group (39%), followed by business (24%) miscellaneous other (15%) (Table 1). Mangrove harvesting as

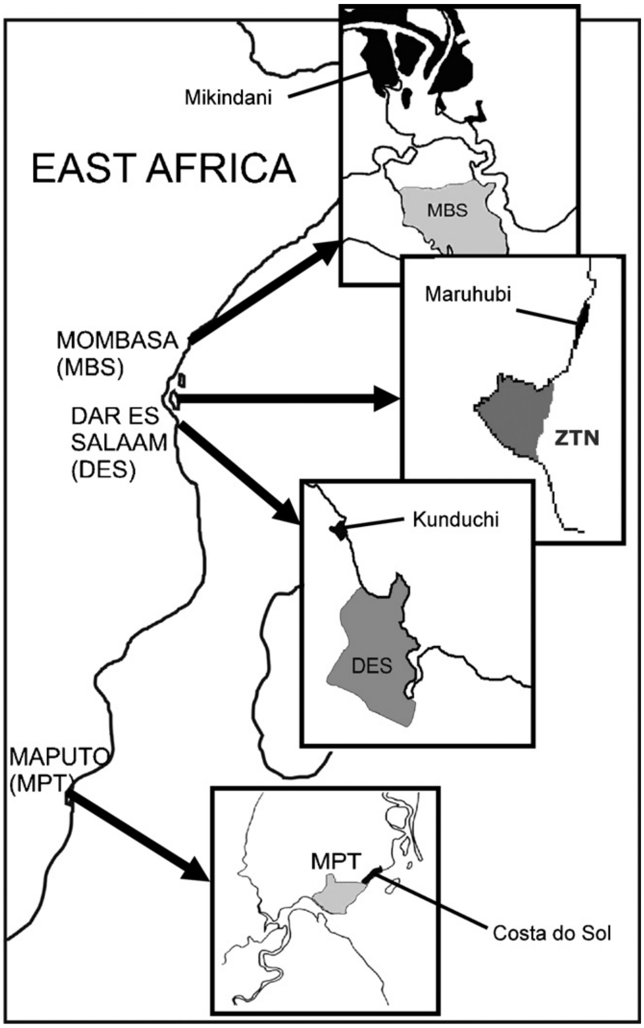

Fig. 2. Overview of sample sites. Black areas indicate the mangroves in close proximity to each surveyed community.

an occupation accounted for 8% of the sample, while marine product collection, fish trade and farming all represent 4% each. Forty-five percent of all respondents visited the mangroves more than twice a week, 32% once or twice a week, and 23% make less than one trip per week to the resource (Fig. 3A). In terms of mangrove dependency there is a clear trend of decreasing dependency across sampled communities, as measured by frequency of mangrove visits, from Mozambique (Costa do Sol) > Kenya (Mikindani) > Zanzibar (Maruhubi) > Tanzania (Kunduchi Pwani) (Fig. 3A). A similar pattern is revealed if looking at mangrove dependency as reflected by harvest of subsistence products (Fig. 3B). Forty-nine percent of all respondents harvest subsistence products from the mangroves. However, looking at mangrove subsistence use at each location shows a decreasing trend from Mozambique > Kenya > Zanzibar > Tanzania (Fig. 3B).

4.2. Perceived pollution and risk

This section presents people's perceptions of pollution in mangroves and surrounding waters—both in general and with specific reference to sewage. Table 2 shows how respondents define pollution. It also shows the perceived sources of pollution, in general, and specifically in the mangroves. Most respondents were able to clearly define pollution (Table 3). For perceived pollution in mangroves and for sewage pollution in mangroves specifically, we see very similar figures. This trend holds across both gender and occupation. Only in Mozambique did respondents state that there was no pollution at all in the mangroves (30%). In all other locations those who did not clearly perceive any pollution claimed they did not know. Kunduch Pwani (mainland Tanzania) stands out as only 43% did not think there was any pollution from sewage in the mangroves at all.

Perceived existence of general and sewage specific pollution showed little difference between gender (Table 3). However, when asked about sources of pollution in the mangroves women are clearly more concerned with sewage than men. Dirty surroundings, sewage, garbage and unsustainable use of resources were the most prominent sources of pollution listed across all respondents, regardless of gender and occupation but there are differences

Table 1
Distribution of occupations across vulnerability categories. Column subtotals are calculated based on the total sample size for each occupation. Row subtotal is calculated based on the sample size of each location.

	Mangrove harvester		Fishing		Fish trade		Marine product collection		Domestic		Business		Farming/Ag		Misc other		Total	Total
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%		
n and % of *N* per occupation	11	8	53	39	5	4	6	4	4	3	32	24	5	4	20	15	136	100%
High vulnerability																		
Costa do Sol	0	0	13	43	0	0	6	20	1	3	1	3	1	3	4	13	26	87%
Mikindani	4	13	7	23	2	7	0	0	0	0	4	13	2	7	2	7	21	70%
Maruhubi	5	33	2	13	0	0	0	0	0	0	4	27	0	0	0	0	9	73%
Kunduchi Pwani	0	0	17	28	1	2	0	0	0	0	3	5	0	0	1	2	21	36%
Subtotal	9	75	39	74	3	60	6	100	1	25	12	38	3	60	7	35	80	59%
Medium vulnerability																		
Costa do Sol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	3%
Mikindani	0	0	1	3	0	0	0	0	1	3	0	0	1	3	0	0	3	10%
Maruhubi	2	20	0	0	0	0	0	0	0	0	2	13	0	0	0	0	6	33%
Kunduchi Pwani	0	0	1	2	1	2	0	0	0	0	11	18	0	0	4	7	18	28%
Subtotal	2	27	2	4	1	20	0	0	1	25	13	41	1	20	5	25	25	18%
Low vulnerability																		
Costa do Sol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	3	10%
Mikindani	0	0	4	13	0	0	0	0	2	7	0	0	0	0	0	0	6	20%
Maruhubi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Kunduchi Pwani	0	0	8	13	1	2	0	0	0	0	7	11	1	2	5	8	22	36%
Subtotal	0	0	12	23	1	20	0	0	2	50	7	22	1	20	8	40	31	23%

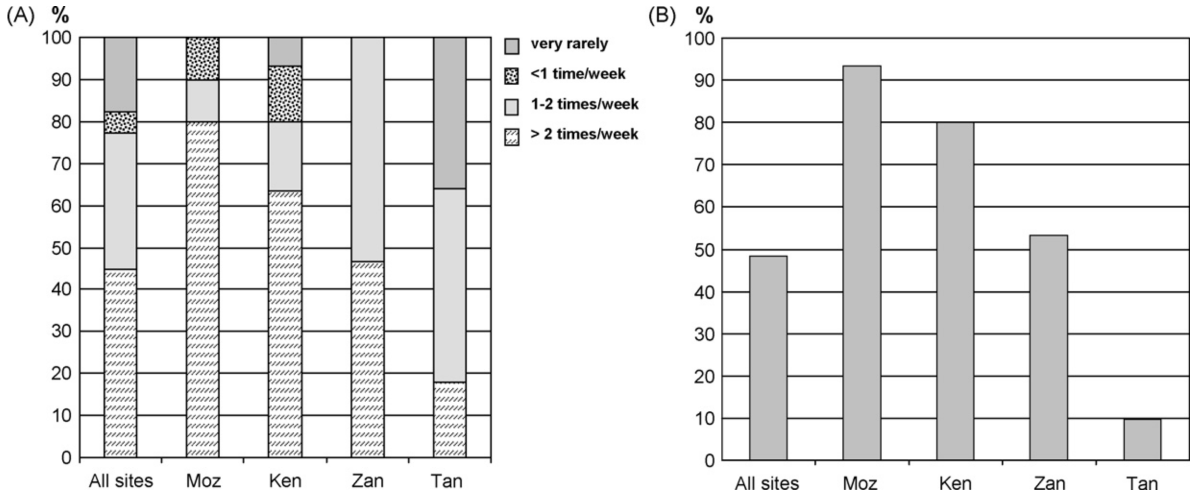

Fig. 3. (A) Frequency of mangrove visits, as stated by respondents. Expressed as percentage of the entire population sampled within each sampled location. (B) Harvest of mangrove subsistence products, as stated by respondents. Expressed as the number of individuals and percentage of the sample from each sampled location and all sites combined. For both figures Moz = Maputo, Mozambique, Ken = Mombasa, Kenya, Zan = Zanzibar Town, Zanzibar/Tanzania, and Tan = Dar es Salaam, Mainland Tanzania.

across sites (Table 2), which are explored in the multivariate analysis below.

Over half of all respondents, irrespective of gender and occupation, could not offer an opinion on what harmful substances sewage might contain (Table 4). Of those respondents who indicated risk, women were more likely to name bacteria while men more often mentioned chemicals, and both genders were concerned with garbage (Table 5). Cross-site comparisons also showed differences. Kenyans and Tanzanians (mainland) were clearly more concerned with harmful substances in sewage (Table 4). The sources of concern also differ across locations with garbage being of primary concern in Kunduchi Pwani (mainland Tanzania) wile in Mikindani (Kenya) respondents were more likely to mention bacteria (Table 5). If we move from a general level of perceived risk, to risk to self, we see that in Kunduchi Pwani and Costa do Sol respondents were much less concerned than the other surveyed communities. Over half (59%) of Tanzanian respondents were not concerned with any risk to themselves. Similarly, looking at the results across gender, women (40%) were much more concerned with disease than men (24%) (Table 5). Asked about risk to self, many respondents also chose to differentiate between direct risks to humans, such as health issues, and more indirect risks such as degraded environment and effects on livelihoods.

Perceived risks and effects of sewage on natural resources, upon which many livelihoods depend, were also investigated. Across countries, gender and occupation, there was a general consensus about perceived effects of sewage on animals and edible marine products (predominantly negative). For effects on trees, no clear trend was apparent and in fact many respondents, across all locations, gender and occupation, did not know, or would not provide an opinion on the effect on any of the resources asked about. Forest products were generally seen as less impacted by sewage than animals although some differences exist across occupations. Most respondents were predominantly concern with contamination of marine food products.

4.3. Vulnerability categories

A total of 80 respondents (59%) were grouped in the high vulnerability category, based on their vulnerability scores. Eighteen percent fell into the medium vulnerability category and 23% were classified as having low vulnerability. For the entire sample

Table 2
Perceived sources of pollution.

	Dirty air, water forest	Sewage	Garbage	Unsustainable use of resources	Interference w nature	Introduction of unwanted substances in the environment
How do you define pollution?						
Costa do Sol	20	7	53	0	7	0
Mikindani	40	37	27	0	17	13
Maruhubi	40	7	20	53	0	0
Kunduchi Pwani	11	21	23	72	8	0
Women	23	15	40	35	10	0
Men	23	23	25	40	8	5

	Dirty air, water forest	Sewage	Garbage	Unsustainable use of resources	Introduction of unwanted substances in the environment
Perceived sources of pollution in peri-urban mangroves					
Costa do Sol	37	13	33	0	0
Mikindani	0	67	7	0	0
Maruhubi	13	60	27	20	7
Kunduchi Pwani	5	18	2	64	3
Women	10	52	19	23	2
Men	13	22	9	35	2

Note: Individuals can respond to more than one category.

Table 3
Perceived pollution.

	Clearly stated perception of pollution	Unsustainable use of resources	Do not know
How do you define pollution?			
Costa do Sol	73	7	20
Mikindani	80	0	20
Maruhubi	100	0	0
Kunduchi Pwani	95	0	5
Women	85	4	10
Men	57	32	11
	Yes	**No pollution**	**Do not know**
Is there any pollution in the mangrove forest or in the surrounding waters?			
Costa do Sol	63	30	7
Mikindani	67	0	23
Maruhubi	100	0	0
Kunduchi Pwani	75	0	25
Women	83	6	10
Men	72	7	22
	Yes	**No**	**Do not know**
Is there any sewage pollution in the mangrove forest or in the surrounding waters?			
Costa do Sol	83	10	7
Mikindani	83	7	10
Maruhubi	93	7	0
Kunduchi Pwani	54	43	3
Women	79	17	4
Men	67	27	6

Table 4
Perceived risk for humans from sewage.

	Indication of perceived risk	Do not know	
Perception of harmful substances in sewage			
Costa do Sol	20	80	
Mikindani	50	50	
Maruhubi	20	80	
Kunduchi Pwani	52	48	
Women	40	60	
Men	42	58	
	Indication of perceived risk to humans	**General risk/ degradation of environment/ livelihood effects**	**Do not know/no effect/positive effect**
Perceived risk to self from sewage exposure			
Costa do Sol	20	20	60
Mikindani	20	50	30
Maruhubi	53	20	27
Kunduchi Pwani	33	8	61
Women	40	17	44
Men	24	24	52

60% of all men and 56% of women fall into the high vulnerability category, 15% and 25% of all men and women, respectively fall into the medium vulnerability category, while 25% and 19%, respectively are categorized as having low vulnerability. Looking across sites, 81% of male respondents in Mozambique and 74% in Kenya were highly vulnerable compared to 43% in Tanzania. Similarly high numbers of women were found in the high vulnerability category in Mozambique (100%) and Kenya (64%). For Zanzibar 69% of women sampled were highly vulnerable while only 13% of Tanzanian women are found in this category. Instead the majority of Tanzanian women were spread evenly across the medium (40%)

Table 5
Perceived sources of risk from pollution.

	Bacteria/disease/harmful org	Chemicals	Litter/garbage	No pollution	Do not know	
Sources of harmful substances in sewage						
Costa do Sol	0	0	20	10	70	
Mikindani	30	7	17	0	50	
Maruhubi	20	13	0	13	67	
Kunduchi Pwani	2	7	49	0	48	
Women	17	17	19	4	54	
Men	6	0	36	2	56	
Business	18	12	35	0	41	
Casual worker	0	0	29	0	71	
Domestic work	25	25	13	0	50	
Farming	20	20	0	0	80	
Fish trade	0	0	50	0	50	
Fisherman	4	2	37	4	56	
Mangr harvest	18	0	9	9	64	
Marine prod	0	0	17	17	67	
	Concerned with disease	**Risk perceived but not explicitly defined**	**Affects ecosystem/ livelihood (−, effect)**	**No effect**	**(+) Effects**	**Do not know**
Sources of perceived risk to self from sewage exposure						
Costa do Sol	20	20	0	30	0	30
Mikindani	20	27	27	0	3	27
Maruhubi	53	53	0	0	0	27
Kunduchi Pwani	33	5	2	59	0	2
Women	40	21	6	25	0	19
Men	24	17	7	38	1	15
Business	47	15	0	35	0	9
Casual worker	14	14	0	57	0	14
Domestic work	38	13	13	13	0	25
Farming	20	20	40	40	0	0
Fish trade	50	0	0	25	0	25
Fisherman	19	20	7	35	2	19
Mangr harvest	36	45	18	0	0	18
Marine prod	33	0	0	33	0	33

Note: Individuals can respond to more than one category.

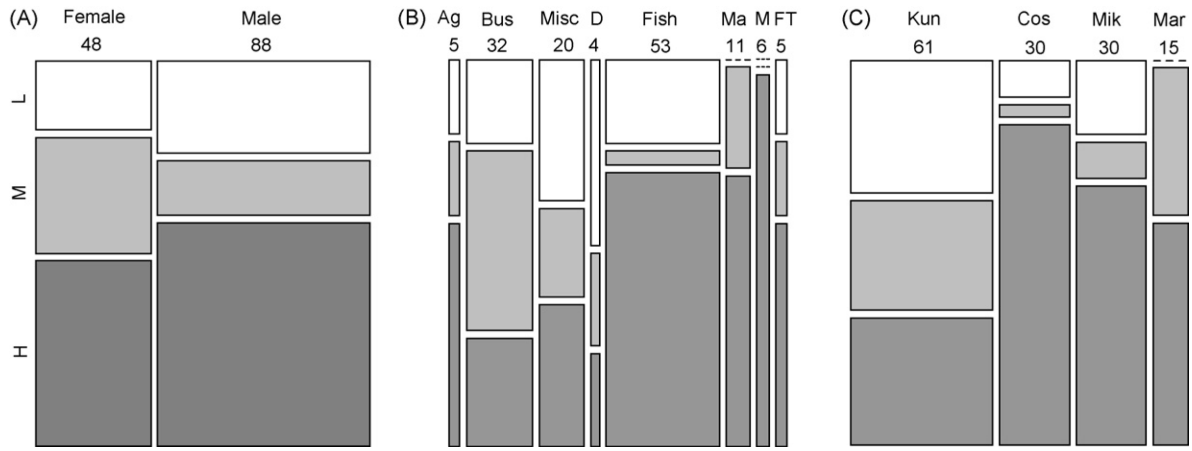

Fig. 4. Plots of the relative frequencies of variables, cross-tabbed against vulnerability category. The size of each block reflects the frequency of each combination of variable and vulnerability category such that the height of the bars indicate to what degree the sample represented by that variable falls within a certain vulnerability category. The width of the bars indicates the relative sample size of that variable in relation to the other variables in the same chart (numbers above each bar). The figure shows gender (A), occupations (B), and locations (C) across vulnerability categories. Vulnerability categories, shown on the left vertical axis, apply across all three charts and are also indicated by colour (H = high (dark grey), M = medium (grey), L = low (white)). For occupations the abbreviations refer to occupations in the following way: Ag = farming, Bus = business, Misc = miscellaneous other, Dom = domestic work, Fish = fishing, Ma = mangrove harvesting, M = marine product collection, and FT = fish trade.

and low vulnerability categories (47%). In Zanzibar 31% of women were found in the medium category and none in low.

Table 1 summarizes the distribution of respondents across vulnerability categories with respect to occupation. Fishermen were the group with the highest proportion (74%) represented in the high vulnerability category (Fig. 4). For many of the other occupations the majority of individuals are also found in the high vulnerability category. For example, mangrove harvesters (75%), fish traders (60%), marine product collectors (100%), and farmers (60%) are all highly vulnerable according to this categorization. Occupations such as domestic, business and miscellaneous other work form a sharp contrast with only 25–38% in the high vulnerability category. However, note that some of the occupational categories are represented by only a limited number of individuals.

Fig. 4 illustrates the relative distribution of gender, occupation and location cross-tabbed against each vulnerability category. χ^2-tests were conducted to test how this distribution differed from a purely random distribution. Results show that gender tested against vulnerability categories was close to, but not significantly different at the 0.05 level ($\chi^2 = 5.20$, d.f. = 2, $p = 0.07$) (Fig. 4A), while the distribution of occupations across vulnerability types was significantly different from random distribution ($\chi^2 = 39.3$, d.f. = 14, p-value < 0.001). Fig. 4B shows that, e.g. fishermen, mangrove harvesters, and marine product collectors are more heavily represented in the high category while businessmen/women are fairly evenly distributed and miscellaneous other work and women involved in domestic work are found primarily in the low category. Locations also differed in their distribution across vulnerability categories ($\chi^2 = 32.53$, d.f. = 6, $p = 0.013$). Fig. 4C shows Mikindani, Costa do Sol, and Maruhubi to all be heavily represented in the high vulnerability category while respondents from Kunduchi Pwani are almost evenly distributed across the categories.

4.4. Multivariate exploration of vulnerability differences between groups

Fig. 5 shows Principal Component Analyses with all respondents plotted according to their responses to questions included in the Exposure, Risk Perception and Sensitivity component, respectively. The patterns observed in the PCAs reflect the variance in the sample as calculated based on all the coded responses (variables) within Exposure, Risk Perception and Sensitivity, respectively. These patterns can be further explored by looking at which of the responses contribute most to the clustering of respondents from the same location and are summarized below. However, note that the cumulative percentage of explained variability is relatively low due to fairly high variability within some country samples (cumulative percentage variance explained for Exposure = 32% (1st and 2nd components), Sensitivity = 38% (1st and 2nd components)). Both plots show Kunduchi Pwani respondents to be distinctly clustered along the lower parts of the 2nd (Fig. 5A) or 1st (Fig. 5B) principal component. For Exposure and Risk Perception (Fig. 5A) Costa do Sol is characterized by lower perceptions of risk from sewage, a logical consequence as most of these respondents also did not perceive sewage to be a problem. Instead they saw litter as a main source of pollution. Mikindani is characterized by high frequencies of mangrove visits (9 or more/month) and a high perception among respondents of sewage pollution in the mangroves. Zanzibar Town clusters on the basis of respondents predominantly characterizing pollution as unsustainable use of resource rather than introduction of any unwanted substances in the mangroves. The Kunduchi Pwani clusteris partly explained by respondents not seeing an issue with sewage in mangroves and consequently little risk or effect of sewage on themselves.

For Sensitivity (Fig. 5B) we note that Kunduchi Pwani again clusters slightly apart from the other locations as a result of few Tanzanian respondents harvesting subsistence products from the mangroves and few relying on mangroves for their primary income. Consequently they felt less impacted by loss or inaccessibility to mangroves. The remaining sites are all characterized by various concerns degradation of various ecosystem goods and services in mangroves, and consequent income loss or living expenses.

5. Discussion

There is a slight differentiation among countries with respect to the distribution of occupational groups with a higher proportion of business men/women in Tanzania (34%) and Zanzibar (40%) compared to Mozambique (3%) and Kenya (13%). Collection of marine products (i.e. gleaning) as an income source is only represented in the Mozambique sample, and while over 50% of Zanzibar respondents get their primary income from mangrove

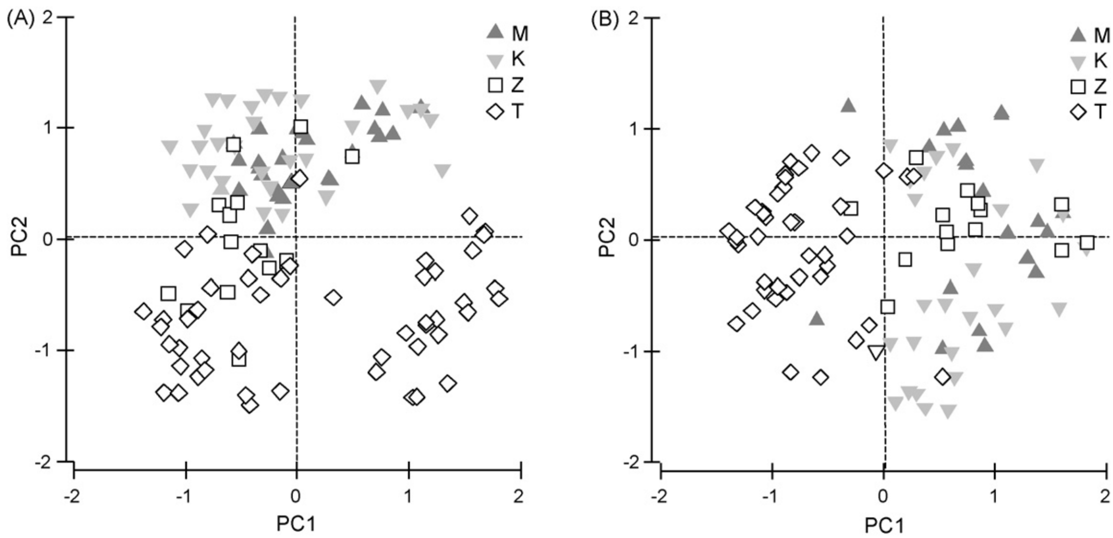

Fig. 5. Principal Component Analysis of responses to questions within the (A) Exposure and Risk Perception and (B) Sensitivity (resource dependency) components. Symbols represent respondents in each of the surveyed communities, indicated here by letters representing countries: M = Mozambique, K = Kenya, Z = Zanzibar, and T = Mainland Tanzania. For Exposure and Risk Perception the 1st and 2nd principal components explain 32% of the variance, and for Sensitivity the1st and 2nd principal components explain 38% of the variance.

harvesting no one in the Mozambique sample listed this occupation. The patterns of mangrove dependence shown in Fig. 3 likely reflect this occupation distribution across countries to some degree. Since a form of purposive sampling was conducted, and percentage representation across populations does not reflect a purely random sample of all citizens in these countries, or even municipalities, conclusions at the country and municipal level should thus be drawn with care from these patterns. Rather the results should be looked at on the basis of each occupational category, as a means of increasing our understanding of sewage related vulnerabilities associated with it and likely to affect members of these and similar communities belonging to each of the occupations discussed here.

5.1. Cognitive sources of pollution and risk perception

Across the entire sampled population, a majority perceive pollution and clearly define it but how pollution is defined varies across locations. This is also reflected in PCA based on questions of exposure and risk (Fig. 5A), where Tanzania clearly differentiates itself. One reason for this distinct cluster is due to the relatively higher homogeneity among Tanzanian respondents with respect to certain questions, e.g. that there is no sewage pollution in the mangroves. However, low perception of sewage in the mangroves was also a characteristic of the Mozambique sample but this cluster was distinguished from Tanzanian respondents by a dominant view that pollution problems in the mangroves are more a matter of garbage and litter. Kenyan respondents, on the other hand, were quite concerned about sewage pollution. These differences among countries obviously reflect the differences in current conditions. For example, the Kenyan population was sampled in a community located near an effluent discharge point, and consequently this is likely to affect respondents' perceptions of sewage. In other sites, such as Maputo and Dar es Salaam, sewage discharge is more diffuse and consequently not as highly perceived by respondents, as evidenced in the results above. This kind of diversity in perceived pollution has been seen in other studies (Bickerstaff and Walker, 2001). Studies also suggest pollution perception is influenced by how tangible and observable the pollution is (i.e. the nature of the pollution) (Barker, 1976; Zeidner and Shechter, 1988). This is tied to the cognitive heuristics which all individuals make use of to interpret the world. In the area of risk, Tversky and Kahneman (1982) have shown that the availability heuristic is particularly relevant as it concerns people's ability to estimate the frequency or probability of events on the basis of how easy it is to think of an example. Therefore, if an event such as sewage discharge is not something frequently observed by an individual, it is less likely that this type of threat will receive a high probability when calculating risk.

Heterogeneity in risk perception has been observed among pastoralist groups in East Africa (Smith et al., 2001). In this study such heterogeneity is seen by Mozambican and Tanzanian respondents being characterized by low perceptions of risk from sewage, a logical consequence as most of these respondents also did not perceive sewage to be a problem. Risk differentiation is also seen across genders. There are no significant differences in overall numbers of men and women who perceived risk from sewage, but we see differences in how they define that risk, i.e. what types of risks they relate to sewage exposure. It is interesting to note that women were more concerned with bacteria and disease, while men defined sewage problems predominantly in terms garbage and are less concerned with disease. In fact many men saw no personal risk at all from sewage exposure. Such gender related differences in risk perception have been noted by many scholars (Davidson and Freudenburg, 1996; Flynn et al., 1994, see also Gustafson, 1998 for review) and suggested reasons include the different social roles played by men and women. For example, women are often more focused on home and family, resulting in increased awareness if risks to their close social sphere, such as health risks (Gustafson, 1998; Jakobsen and Karlsson, 1996). Men on the other hand are often more concerned with risks of unemployment and economic uncertainty.

Other factors have also been seen to affect risk perception. Direct personal experience, for example, seemingly plays an important role in defining how people perceive environmental risk (Bickerstaff and Walker, 2001; Irwin et al., 1999; Macgill, 1987). In our case occupation is largely correlated with gender, such that, e.g. women will never fish. Gleaning (collection of marine products in tidal areas) is, however, mostly undertaken by women and children. Such differences in activities is likely to affect where in the environment a person spends most of his or her time, which in turn can affect how sewage pollution is perceived. However, results presented here show no clear pattern which supports this. On the contrary, individuals in occupations which are less dependent on the mangrove resource appear more concerned with disease threats and personal risk than individuals heavily involved in mangrove resource extraction (Table 5). It could be argued that this is an effect of livelihood choices not being static and individuals having changed livelihood strategies as an effect of high perceived risk. However, our data does not support this. Of the 43 respondents (32% of entire sample) that scored low indicating high perceived risk (Appendix B) only 13 had changed occupation in the last 5 years and only one had changed from a mangrove related livelihood to a non-mangrove related occupation. This does not preclude that such 'switching-out' of resource-based occupations does not occur but it is not correlated with perceptions of high risk in our sample. Furthermore only 21% of the entire sample had changed occupation recently indicating that livelihood choices are not markedly dynamic. Education was tested for but variation in educational level is low (most respondents have only completed primary education) and could not explain this difference. Similarly, Radcliffe and Klein (2002) did not find any relationship between risk perception and education in a developed country context. Nonetheless, knowledge of the hazard and consequences of exposure is believed to have a strong impact on risk perception (Weinstein, 1999) and consequent behaviour (Janz and Becker, 1984). Arguably, if an individual is not aware of the consequences of sewage exposure, he or she will be relatively more vulnerable than a similar respondent who is aware of potential effects. This is one of the assumptions upon which the following discussion of vulnerability rests. The fact that many respondents perceived a general risk related to sewage but did not link it directly to human health could signal existence of the type of systematic underestimation of risk referred to as unrealistic optimism (Radcliffe and Klein, 2002; Weinstein, 1980). Unrealistic optimism has also been seen to affect response to a risk (Becker and Maiman, 1975; Janz and Becker, 1984) and thus has implications for the vulnerability of unrealistically optimistic individuals.

5.2. Stakeholder vulnerability

In the context of vulnerability it is interesting to note that nearly 60% of respondents do not perceive any harmful substances in sewage, nor do they see how sewage may pose a risk to them. This pattern is consistent regardless of gender and occupation. As knowledge and understanding of the potential hazards of sewage is likely to affect risk perception and poor understanding likely to result in more optimistic (less risk perceptive) individuals (Weinstein, 1980, 1999), this is an important assumption upon which the following vulnerability discussion rests.

Looking at the general distribution of respondents from each community across vulnerability categories it is interesting to note that Kunduchi Pwani has the least vulnerable population (H = 34%, M = 29%, L = 36%) (Table 1 and Fig. 4C). In comparison, 87% of all Costa do Sol and 70% of Mikindani respondents fall into the high vulnerability category based on their answers. For Kunduchi Pwani this pattern is also observed in Fig. 5B and it is driven by respondents stating lower levels of mangrove subsistence harvest as well as not having their primary income related to mangroves. Consequently they feel less impacted by loss or inaccessibility to mangroves. This is their main cause of differentiation from the other communities where respondents are more generally highly concerned with exclusion from the mangrove resource and its effect on livelihoods.

Based on results presented here we can conclude that surveyed communities in Maputo and Mombasa use the mangrove resources more and thus may be more affected by the use of mangroves as sewage filters than their counterparts in Dar es Salaam. However, the size and condition of mangroves available to respondents at present are likely to have affected the responses. The mangrove resources in Kunduchi Pwani are already severely degraded, so communities may already have lost the benefits provided by mangroves and the low frequency of visits is a result of this. Since economic data for each household was not collected for this survey relative household economic status cannot be verified across countries. Consequently we cannot verify if foregone benefits from potential loss of goods from the mangroves are correlated with lower levels of income. It is, however, a question which should be explored further.

For the entire sample 60% of all men and 50% of all women fall into the high vulnerability category. However, there is no clear pattern with regard to the distribution of gender across vulnerability levels, and most likely it varies across countries as an effect of primary income. On the other hand certain occupations are more vulnerable than others. Although the number of respondents within occupation categories varies (e.g. farmers and marine product collectors are only represented by five and six individuals, respectively) we see that occupations that are tightly connected to the mangrove resource, such as fishermen and mangrove harvesters, are heavily represented in the highest vulnerability category (Table 1 and Fig. 4B). This is an effect of individuals within these occupations perceiving a higher risk from resource exclusion relative to the others. Based on these results it appears occupation is a stronger determinant of vulnerability, as defined in this study, than gender.

Previously conducted assessments and background literature indicate that the poorest members of the community are simultaneously the most reliant on natural resources (i.e. vulnerable to restricted access) (e.g. Castillo et al., 2005; MA, 2005; WRI, 2005), as well as the most vulnerable to sewage related disease spread, such as cholera (Olago et al., 2007). Many studies have shown that, throughout the world, mangroves are commonly used by already disenfranchised or marginalized and poor households (e.g. Rönnback et al., 2007; Walters et al., 2008). Their contribution to household income, which is rarely accounted for in conventional economic estimates of GDP nor in valuation of mangrove resources, has been shown to be considerable (Walters et al., 2008). Consequently, it should be noted that loss of access to mangroves for the communities studied here is likely to have a significant effect on household subsistence. The vulnerability analysis presented in this paper is an analysis of the relative inter-group vulnerability among groups that were à priori defined as most likely to be affected by sewage related pollution in mangroves. Hence, all of the groups here should be viewed as significantly vulnerable (Olago et al., 2007). In effect, our measurement of exposure is based on the current state of exposure, as experienced and perceived by the respondents. The analysis shows that several sites have low perceptions of impact and risk among resource users at present despite known impacts from raw sewage affecting the mangroves. It could therefore be argued that although, and in fact because of it not being perceived by respondents, the community may actually be more vulnerable at present than revealed by the analysis of vulnerability categories.

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Appendix A. Questions used in vulnerability analysis. QUAL: qualitative code; RANK: quantitative code used for assessing scores of respondents for vulnerability category analysis.

Question #	Question level	Code type	Code item score	Question
Exposure				
2				How often do you visit the mangrove (days/month)?
		RANK	3	9 daily (3)
			2	4–8 (2)
			1	1–3 (1)
			0	<1 (0)
20				How do you define pollution?
		QUAL		Dirty surroundings/poor quality of air, water forest
				Sewage/waste water
				Garbage/litter
				Untidy/plant animal material littering
				Unsustainable use of resources
				Disturbance/interference w nature
				Introduction of unwanted substances in the environment
				Do not know
		RANK	0	Clearly stated perception of pollution
			1	Unsustainable use of resources
			2	Do not know
21				Is there any pollution in the mangrove forest or in the surrounding waters?
		QUAL		Dirty surroundings/poor quality of air, water forest
				Sewage/waste water
				Garbage/litter
				Untidy/plant animal material littering
				Unsustainable use of resources
				Disturbance/interference w nature
				Introduction of unwanted substances in the environment
				No pollution
				Do not know
		RANK	0	Perception = yes
			1	Perception = no
			1	Perception = do not know
22	a			Is there any sewage pollution in the mangrove forest or in the surrounding waters?
		RANK	0	Yes
			1	No
			1	Do not know
	b			What harmful, if any, component(s) does sewage carry?
		QUAL		Yes
				Bacteria/disease/harmful orgs
				Chemicals
				Litter/garbage/waste
				Blood and cattle waste
				No pollution
				Do not know
		RANK	0	Indication of perceived risk
			1	Perception = no
			1	Do not know
23	a			How does sewage affect you?
		QUAL		Concerned with disease
				Risk perceived but not explicitly defined
				Affects the forest/animals—affecting livelihood (negative)
				No effect
				Positive effects
				Do not know
		RANK	0	Indication of perceived risk to humans
			1	General risk/degradation of environment/livelihood effects
			2	Do not know/no effect/positive effect
Sensitivity				
1	g			What is your primary and (if any) secondary income?
		QUAL/RANK	2	Mangrove only income source
			1	Mangrove primary income source but 2nd income not from mangroves
			0	Primary income not mangrove related
	i			Do you harvest subsistence products (not for sale) from mangroves?
		QUAL/RANK	1	Yes
			0	No
12	a			What would happen to you or others if mangroves were... severely degraded?
		QUAL		Loose income/livelihood
				Relocate/find alternative livelihood
				Increased expenses due to loss of certain mangrove goods and services

Appendix A (*Continued*)

Question #	Question level	Code type	Code item score	Question
				Acknowledgement of degradation and loss of ecosystem services
				No impact/no significant change perceived
				Do not know
		RANK	1	Negative effects
			0	No impact/do not know
	b			Lost?
		QUAL		Loose income/livelihood
				Relocate/find alternative livelihood
				Increased expenses due to loss of certain mangrove goods and services
				Acknowledgement of degradation and loss of ecosystem services
				No impact/no significant change perceived/cannot happen
				Do not know
		RANK	1	Negative effects
			0	No impact/do not know
	c			Inaccessible?
		QUAL		Loose income/livelihood
				Relocate/find alternative livelihood
				Increased expenses due to loss of certain mangrove goods and services
				Acknowledgement of degradation and loss of ecosystem services
				No impact/no significant change perceived/cannot happen
				Do not know
		RANK	1	Negative effects
			0	No impact/do not know

Appendix B. Range of cut-off values used for vulnerability measures and calculation of vulnerability categories. For assumptions behind categories, see Table 1.

	Score range
Direct exposure[a]	
H = >8 (t/month)	3
M = 4–8	2
L = ≤3	0–1
Perceived risk[b]	
H risk (i.e. low perception)	4–6
M risk	2–3
L risk (i.e. high percept)	0–1
Sensitivity (perceived exclusion)[c]	
H risk (i.e. high percept)	4–6
M risk	2–3
L risk (i.e. low perception)	0–1

[a] Correspond to natural breaks in the frequency data explored with scatterplots.
[b] Cut-off points were set by dividing the range into three sections. The lowest interval (0–1) is motivated by the reasoning that a clear perception/definition of pollution is fundamental to defining risk in relation to it. Hence, 'no definition of pollution' and 'no perceived effects to self' both give a score of 2 and thus immediately places a respondent in the medium interval for this vulnerability component.
[c] Same interval scale (1/3) as (see footnote b).

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