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Resolving coastal conflicts using marine spatial planning

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ABSTRACT

We applied marine spatial planning (MSP) to manage conflicts in a multi-use coastal area of Kenya. MSP involves several steps which were supported by using geographical information systems (GISs), multi-criteria decision analysis (MCDA) and optimization. GIS was used in identifying overlapping coastal uses and mapping conflict hotspots. MCDA was used to incorporate the preferences of user groups and managers into a formal decision analysis procedure. Optimization was applied in generating optimal allocation alternatives to competing uses. Through this analysis three important objectives that build a foundation for future planning of Kenya's coastal waters were achieved: 1) engaging competing stakeholders; 2) illustrating how MSP can be adapted to aid decision-making in multi-use coastal regions; and 3) developing a draft coastal use allocation plan. The successful application of MSP to resolve conflicts in coastal regions depends on the level of stakeholder involvement, data availability and the existing knowledge base.

1. Introduction

Most coastal areas of the world are multiple-use areas where different human activities take place. Coastal areas attract a variety of competing uses which sometimes overlap causing adverse effects on each other (user–user conflicts) (Cicin-Sain and Knecht, 1998) or impact on the coastal marine environment (user-environment conflicts) (Burger and Leonard, 2000; Douvere et al., 2007).Consequently many countries are making attempts to manage conflicts between coastal resource users and halt environmental damage.

Integrated coastal zone management (ICZM) (Cicin-Sain and Knecht, 1998) and Ecosystem-based management (EBM) (McLeod et al., 2005) are among the many approaches that have been used to implicitly address the management of conflicts among different coastal resource users. These approaches emphasize integration and balancing of multiple objectives in ecosystem planning process (Christie et al., 2005; UNEP, 2011). GIS is often used within these approaches to enhance spatial management (Vallega, 1999, 2005). Whilst these approaches have enhanced gains in conservation and integrated management, new trends of conflicts are now emerging as demand for coastal resources increase (such as oil and gas, tourism, fisheries and conservation). This calls for more efficient ocean use strategies that balance economy, environmental protection and social demands.

Marine Spatial Planning (MSP) has recently been promoted as one of the strategies that can help address complex conflicts in coastal and marine areas (Ehler and Douvere, 2007; Schultz-Zehden et al., 2008; Ehler and Douvere, 2009). MSP is a way of improving decision-making and delivering an ecosystem-based approach to managing human activities in the marine environment. It is a planning process that enables integrated, forward looking, and consistent decision-making on the human uses of the sea (Ehler and Douvere, 2007). MSP is increasingly being applied to develop marine zoning and allocation plans that address multiple-use conflicts (Gubbay, 2005; Douvere et al., 2007; Ehler and Douvere, 2009; Agostini et al., 2010; Day, 2002). It focuses on management of marine areas where the principal objective is to balance ecological, economic and social interests (Douvere and Ehler, 2008). The inclusion of social criteria in decision-making represents a move towards post normal science where facts are uncertain and the stakes are can be high (Funtowicz and Ravetz, 1994). Multicriteria decision analysis is used as a framework to identify why social conflicts exist and how alternative solutions might be evaluated (Munda, 2004).

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A suite of software based tools are now available for MSP projects (EBM, 2010). There are however few examples of how MSP has been applied in coastal waters which include bays, estuaries and near shore marine waters.

In this paper we report findings of a spatial coastal conflict resolution process that utilized the MSP process. Motivated by the multi-use conflicts (user–user conflicts and user-environment conflicts) in Kenya's coastal area we have attempted to apply MSP to identify existing conflicts and deal with allocation problems. The utility of MSP in determining and addressing coastal conflicts and the implementation challenges are discussed.

2. Methodology

2.1. Study area

This study was carried out in Mombasa's coastal area in Kenya. This area is under the jurisdiction of the Kenya Wildlife Service (KWS) which is legally obliged to make planning decisions for the Mombasa Marine National Park and Reserve (MMNP&R) which covers a total area of 200 km^2. This study focused on the highly used area of MMNP&R measuring 38.08 km^2 (Fig. 1).

The Mombasa coastal area is a complex mosaic of human activities and habitats. The main uses typically fall under fishing, tourism and conservation. The habitats include a reef enclosed lagoon (including its submerged areas of sand/mud flats and seagrass beds) and its shores with extensive sandy beaches. These habitats perform several environmental and biodiversity functions and services including genetic stock of biodiversity, fisheries and tourism (McClanahan et al., 2005). Consequently many users are attracted to this coastal area leading to increased conflicts. The documented conflicts are between: 1) artisanal fishers and tourism operators; (2) conservation and fishing sectors; (3) different fisher groups; and (4) nontraditional beach seine fisheries and trap fishers (Muthiga, 2003; McClanahan et al., 2005; Frontani, 2006). Conflicts are usually exacerbated by different government agencies which are responsible for licensing different activities in the area without appropriate consultation. For example, after the establishment of the MMNP&R, disagreements between KWS and the Fisheries Department increased because of the competing mandates of conservation and increasing fish catches respectively (McClanahan et al., 2005). The Tourism Department also increased the number of licensed water sport activities the MMNP&R as a way of increasing tourism revenues without due regard to environmental damages caused by mass tourism and the resulting conflicts for access. Existing sector regulations are also fragmented and are not well understood or integrated. These conflicts have hindered the effectiveness of management of important ecological areas (Muthiga, 2003, 2009).Emerging conflicts are usually addressed in an *ad hoc* manner because there are no legal instruments for coastal conflict resolution and formal mechanisms to allow stakeholders participation in planning and decision-making processes (Muthiga, 2009). This study therefore undertook to address existing conflicts using a marine spatial planning approach.

2.2. Steps followed in MSP

Conflict analysis and resolution followed the general MSP process based on the work of Ehler and colleagues (Ehler and Douvere, 2009) (Fig. 2). Data describing the coastal marine habitats and human activities was incorporated in the step by step MSP process to guide decisions on conflict and allocation of coastal spaces (Ehler and Douvere, 2009; Gilliland and Laffoley, 2008). Geographical Information Systems (GISs), multicriteria decision analysis (MCDA) (Malczewski, 1999) and optimization techniques (Malczewski et al., 1997) supported the steps in MSP. The four main steps in the MSP were: 1) pre-planning; 2) defining and analysing present conflicts; 3) defining and analysing future conditions; and 4) developing alternative allocation plans. These steps allowed for the inclusion of stakeholders at different stages of the process (Guenette and Alder, 2007; Gopnik et al., 2012). The MSP was devised using a 'bottom up' approach, with top-down steering and guidance.

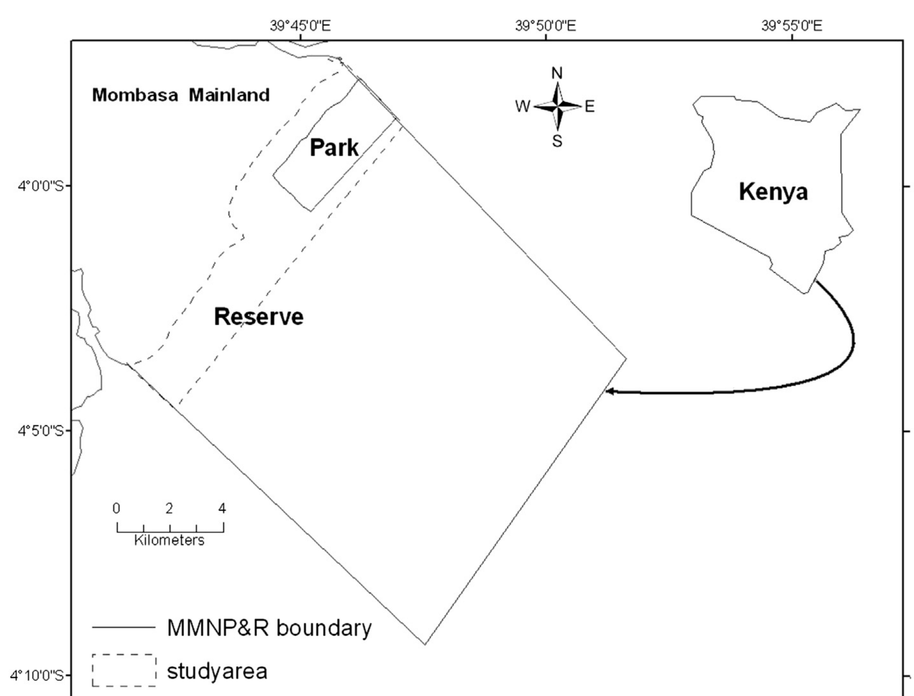

Fig. 1. Map showing location of study area, Mombasa Marine Nature Park and Reserve (MMNP&R), Kenya.

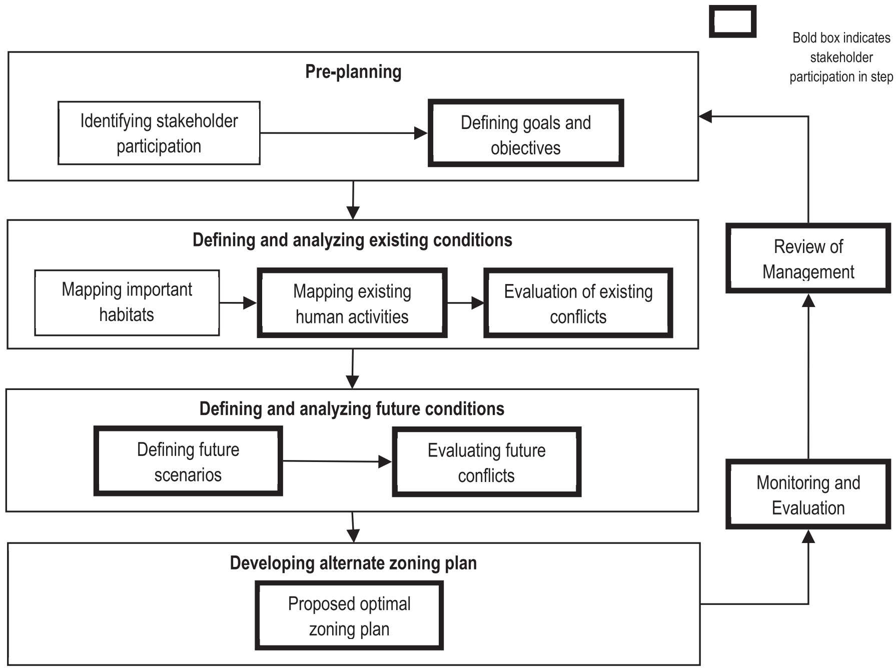

Fig. 2. Steps followed in the marine spatial planning process (adapted from Ehler and Douvere (2009)).

2.3. Pre-planning

The pre-planning process involved identifying stakeholders to participate in the conflict resolution process and defining desired conflict resolution outcomes (goals and objectives). Stakeholder engagement is an inherent aspect of MSP (Gilliland and Laffoley, 2008; Guenette an Alder, 2007; Gopnik et al., 2012) and it was critical to different stages of the conflict resolution process. Three considerations were made prior to involving stakeholders to ensure expected results at least costs: 1) who should be involved; 2) how should stakeholders be involved; and 3) when should stakeholders be involved (Maguire et al., 2012)? Coastal resource users and management agencies whose activities contributed to the conflicts were identified and involved in the process at different stages in the MSP process (Fig. 2). The MMNP&R identifies user conflicts as one of the issues that the MPA needed to resolve to enhance effective management. The management plan describes existing interagency conflicts and resource use conflicts and the players involved in the conflicts (Weru, 2001). The management plan details conflicts related to control and access in the MMNP&R which results from: 1) same resource users (between fishers using different fishing gears); 2) different resource users (e.g. between fishers and divers); and 3) between management agencies (e.g. KWS and the Fisheries Department). The first list of stakeholders was derived from the MMNPR management plan. This included stakeholders who are direct users of the marine resources e.g. fishers and tour operators and the regulatory agencies. This was done solely by the MPA management team to determine who should eventually become part of the planning process. The list of stakeholders was broadened by soliciting input from the already identified stakeholders who helped in identifying other stakeholder groups that were important for the process. The stakeholders were then classified as either primary or secondary stakeholders (Bunce et al., 2000). Primary stakeholders were competing user groups whose activities contributed directly to use conflicts. This category was represented by 16 user groups that were clustered into five coastal uses: habitat protection; sea access and anchorage; water recreation; beach activities; and artisanal fishers. The secondary stakeholders were three government agencies responsible for regulating the coastal uses: the Kenya Wildlife Service (KWS); the Tourism Department (TD); and the Fisheries Department (FiD) (Table 1). The final list of 16 user groups was derived based on a conflict analysis using a matrix that listed all identified stakeholders on both axes and establishing the relations interaction between each group. This was done as a purely technical exercise without direct involvement from the various groups. The secondary stakeholders list was developed based on the selected user groups and identifying who licences their activities. Only three government agencies are currently involved in licensing different users groups in the in the MMNP&R: KWS is responsible for site management of the MMNP&R; TD is responsible for licencing users under coastal uses 2,3 and 4; and FiD is responsible for licensing activities under coastal use (Table 1). After the stakeholders were selected a conflict scoping meeting was held with both primary and secondary stakeholders represented in order to jointly agree on the conflict resolution objectives. The user groups were represented in the meeting by respective group officials. The 16 user groups are formal groups registered by the social service department and each group has elected officials. Each user group was represented at the meeting by three officials. The conflict scoping meeting reviewed the current management practices including management objectives, mandatory regulations and voluntary agreements relating to the MMNP&R. This was done to inform conflict resolution objectives and spatial allocation decisions. Clear objectives provide the context for the MSP process (Gilliland and Laffoley, 2008). The objectives of this conflict resolution were formulated as: 1) minimize existing conflicts in the Mombasa coastal area to the lowest level; and 2) to allocate spaces optimally to competing human activities.

2.4. Defining and analysing existing conditions

The second step in the MSP process was to analyse existing spatial conflicts. We used GIS based multicriteria decision analysis

Table 1
Criteria (habitats and human activities) used in the MCDA and description of stakeholders associated with respective criteria.

Coastal uses	Criteria for MCDA	Description of spatial data	Description of user group
1. Habitat Protection	Seagrass beds	Locations of seagrass beds. Sea grass beds are areas of submerged vegetation associated with coral reefs.	The MMNP&R manager and staff
	Coral reef	Location of corals and the reef which occurs as a fringing reef and patch corals.	
	Intertidal mud/sand flats	Locations of habitats that are periodically inundated and exposed to the tidal ebb. The habitats are foraging grounds for many shore and migratory birds.	
	Sandy beach	Areas characterized by bare sand. They are often slightly vegetated.	
	Mixed substrate	These are areas characterised with rubbles and sand that are submerged	
	Turtles nesting grounds	Important nesting areas for endangered marine turtles especially the (*Cheloniamyda*)	
2. Sea access and anchorage	Sailing	Locations used by water sport operators for sailing, windsurfing	Beach hotels water sport owners with surfs and local tour operators using traditional wooden boats with sails for recreational activities
	Jet skiing	Jet ski designated areas in the MMNP&R	Beach hotel water sports operating jets skis for hire
	Anchoring, mooring of vessels	Areas used for vessel anchoring	Local boat operators who use inshore areas along the beach to anchor their vessels
3. Water recreation	Scuba Diving	Location of diving areas including areas of wreck dive	Diving schools
	Snorkelling	Locations used tourists for snorkelling	Diving schools and local boat operators
	Inshore recreation	Locations of Intertidal areas used by public for swimming	Tube renters – these are groups of people renting out floatation devices for swimmers and who dominate the inshore areas of the MMNP&R Pedal boat renters who rent out pedal boats along the beach
4. Beach activities	Curio stalls	Location of curio traders on the beach	Curio dealers who sell their wares on the beach
	Safari selling	Location of safari sellers on the beach	Safari sellers who are tour operators operating along the beach
	Boat operations	Location of boat operators on the beach	Members of the Mombasa Boat Operators Association operating glass-bottom boats
	Other activities	Location of various activities on the beach	Other beach operators including food vendors
5. Artisanal fishing	Basket/trap fishing	Locations where fishers use basket traps	Fishers using basket traps and non-motorised vessels
	Gill netting and line fishing	Areas where fishers use gill nets and lines	Fishers using gill nets with motorised on non-motorised vessels
	Gleaning	Locations mainly on the reef where fishers collect octopus and other invertebrates	Fishers who glean for octopus on foot
	Beach seining	Locations of used by fishers using beach seines	Fishers using drag nets in intertidal areas
	Landing and mooring sites	Areas used by fishermen for vessel anchorage and landing catches	Fish vendors and all groups of fishers

(GIS-MCDA) in a structured decision framework to combine a set of geographical data (coastal habitats and human activities) and their relative weights of importance to conflicts as elicited by stakeholders (Malczewski, 2006). This approach has been used widely in environmental decision-making for formalizing and addressing competing decision objectives (Malczewski, 1999; Regan et al., 2007; Yatsalo et al., 2009). In coastal areas it has been used in addressing conflicts and for conservation planning (Villa et al., 2002; Brown et al., 2001; Brody et al., 2004, 2006). GIS-MCDA has been used to support analysis and visualization of spatial incompatibilities and overlapping interests (Heywood et al., 2002).

The first-step in the GIS-MCDA was to gather geographical information on competing human activities and coastal marine habitats which were categorised into five coastal uses (Table 1). Spatial data on coastal habitats were obtained from Kenya Wildlife Service (KWS) GIS database while data on human activities was collected from field surveys with the involvement of competing user groups. Individual user groups participated in field exercises to collect information on geographical positions of their respective use areas. The recruitment of those who participated in the data collection was done at the problem-scoping meeting where the group officials were also asked to submit the names of their members who would work with the project team through the MSP process. The recruitment of those who participated in field data collection was therefore done through the respective groups. The officials of respective groups were given the list of characteristics for stakeholder representatives and asked to select their representatives. They were advised to choose representatives who have support of the group and who can communicate back to the group, those who can make time commitment to actively participate in the entire process and those who have knowledge about the different users in the MMNPR. Many user groups felt that the MSP as outlined in the initial phases of the planning could potentially enhance collaboration and trust between stakeholders and therefore they were eager to participate. Most of the user groups in the MMNP&R carry out their trade on the beach and they communicate with each other on an occasional basis. This communication reduced the barriers among them during the data collection.

Table 1 describes the mapped use areas and the respective user groups. All spatial information was organised and managed in an Environmental Systems Research Institute (ESRI) geodatabase format. For spatial analysis all habitat and human activity data were transformed into Boolean raster map layers. A Boolean raster map layer contains pixel values of 0 and 1, with 1 signifying areas where the habitat or human activity was present and 0 otherwise. In a habitat or human activity map layer, a pixel was denoted by $i(i = 1, 2, \ldots, n)$ and $i = 1$ where habitat or human activity is present and $i = 0$ where not. The value of a pixel i in a habitat or human activity map layer denoted by j was therefore designated as x_{ij} which represented the level of the jth habitat or human activity with respect pixel i.

Since each coastal use and their corresponding habitats and human activities (Table 1) contribute differently to conflicts it was necessary to assign them weights of importance. The Analytical Hierarchy Process (AHP) was used to assign weights of importance (Saaty, 1980). AHP uses numerical pair-wise comparison of the relative importance of one criterion over another (Malczewski, 1999). Pair-wise comparisons were done hierarchically at two levels with participation of both primary and secondary stakeholders. The first level comparisons were made between coastal uses while at the second level comparisons were made between habitats and human uses under respective coastal uses (Table 1). Comparisons at the first level were done by asking: of two coastal uses C_1 to C_g which one contributes more to existing conflicts. The assignment of weights of importance at this level was done by the secondary stakeholders (KWS, TD and FiD). These are the agencies that have respective interest in and knowledge of coastal conservation, tourism and fisheries issues in the MMNP&R. Comparisons at the second level of the hierarchy were done by asking: of two habitats or of two human activities j_1 and j_n which one contributes more to existing conflicts under a respective coastal use C_*? Primary stakeholders under respective coastal uses assigned weights to activities under respective coastal uses (Table 1). The assigning of weights was done as group discussions with the guidance of experts. The results of group discussions were shared in a plenary session where weights were adjusted and agreed. The responses were then compared on the 9 point scale (Table 2). The actual computation of weights for coastal uses and for habitats and human activities was done by extracting the eigenvalues and eigenvectors from the pair-wise comparison matrices. The weight vectors were then synthesized over the hierarchy (Saaty, 1980) to get the actual weights of habitats and human activities $w_j (j = 1, 2, \ldots, n)$ (Table 3). Higher weights indicate a greater relative importance of the habitat or human activity over the other.

Using GIS arithmetic operations the habitats and human activity values x_{ij} were combined with their corresponding weights w_j to determine the coefficients of conflict for individual habitats and human activities. The coefficients served as ratings of the effectiveness of the habitat or human activity in contributing to the conflicts. A high coefficient value indicated a significant contribution to the conflicts. Weighted linear combination method (WLC) was used in GIS (Malczewski, 1999) to combine the habitats and human activity map layers in order to determine the composite map layer with new conflict values R_i (Eq. (1)).

$$R_i = \sum_j w_j x_{ij}. \quad (1)$$

The resulting map output was then standardized using the maximum score linear transformation (i.e. by dividing each value in the map layer by the maximum pixel value) (Malczewski, 2006) (Eq. (2)):

$$R_i' = \frac{R_i}{R_i^{\max}} \quad (2)$$

where R_i' was the standardized overall score for the ith location, R_i was the overall score of the ith pixel and $R_i^{\max}$ was the highest overall score from the summed output. The values of standardized scores ranged from 0 to 1 and were ranked qualitatively (Table 4). The higher the value of the standardized scores the higher level of conflict.

2.5. Defining and analysing future conditions

The purpose of this step was to answer questions on how future management actions will affect spatial conflicts. We assessed conflicts under three potential management scenarios of increasing use of the Mombasa coastal area for: 1) fisheries; 2) recreation (tourism); and 3)protection (conservation).

The same steps used to assess present conflicts were applied. Pair-wise comparisons were done to derive the weight of importance for coastal uses in contributing to future conflicts under the three scenarios. The pair-wise comparison was done only at the first level of the hierarchy by asking: between criterion C_1 and C_g which one is likely to contribute more to conflicts under a particular management scenario. The comparisons were made for all coastal uses under the three potential management scenarios. The weight vectors were then synthesized over the hierarchy to derive the weights of individual habitats and human activities $w_j (j = 1, 2, \ldots, n)$ under the three scenarios. Using GIS arithmetic operations the habitats and human activity values x_{ij} were combined with their corresponding weights w_j to determine the coefficients of conflict for habitat and human activity. The weighted habitats and human activity map layers were summed to get R_i. Standardized map outputs for the three scenarios were computed using Eq. (2) to get R_i'.

2.6. Optimization for spatial allocation

After the identification of the intensity and location of conflicts, the next step was to allocate spaces within the conflict areas to competing users such that the intensity of conflict would be minimized. This was done using optimization techniques. The utility of optimization as a tool for resolving spatial allocation problems is widely recognized (Malczewski, 1999; Aerts et al., 2003). The important factor considered in this allocation problem was to distribute uses within the areas of conflict in a way that will meet user demands and maintain socio-economic and environmental constraints. An optimal allocation plan was therefore one that: minimized the levels of conflicts among competing users; minimized the impact of different uses on critical habitats; and enhanced users' safety. The impacts that the plan aimed to minimize include breakage of corals by fishers and tourists, boat accidents in tourist areas and disagreements between fishers and tour operators over use of common coral sites.

Using the resulting mapped outputs of present conflicts analysis (Fig. 3a), locations of different conflict levels (Table 4) were evaluated using GIS operations to identify habitats and human activities which contributed to conflicts in those locations. The identified activities in a conflict location were then used as variables in the optimization model that determined activity allocations for that location. The optimization model was formulated as 0–1 integer goal program (IPG) (Malczewski, 1999; Malczewski et al., 1997) where the variables are binary and represent two-choice decisions of whether or not to allocate a particular activity to a specific conflict location.

An optimal spatial use pattern was agreed to be one that achieved the two objectives set out at the pre-planning stage, i.e. to reduce existing conflicts to the lowest level and to allocate space optimally to competing uses. These objectives were formulated as

Table 2
The AHP scale for pair-wise comparison.

Intensity of importance	Definition
1	Equal importance
3	Weak importance
5	Essential or strong importance
7	Demonstrated/very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

Table 3
Weights assigned to coastal uses and corresponding habitats and user activities.

Scenarios	Habitats and user activities	Present status		Exploitation		Recreation		Habitat protection	
Coastal uses		α_C	w_j	α_C	w_j	α_C	w_j	α_C	w_j
HP		0.043		0.469		0.046		0.039	
	SG		0.006		0.062		0.006		0.005
	CR		0.018		0.192		0.019		0.016
	IF		0.002		0.027		0.003		0.002
	SB		0.004		0.043		0.004		0.004
	TN		0.009		0.101		0.010		0.008
	MS		0.004		0.044		0.004		0.004
SA		0.093		0.130		0.147		0.104	
	JS		0.036		0.050		0.056		0.040
	SL		0.014		0.020		0.022		0.016
	MO		0.005		0.007		0.008		0.006
	WS		0.038		0.053		0.060		0.043
WR		0.166		0.293		0.080	0.000	0.104	
	SK		0.108		0.190		0.052		0.067
	DV		0.038		0.067		0.018		0.024
	IR		0.020		0.036		0.010		0.013
BA		0.198		0.074		0.155		0.178	
	BO		0.079		0.029		0.062		0.071
	CD		0.038		0.014		0.030		0.034
	SS		0.067		0.025		0.053		0.061
	OT		0.014		0.005		0.011		0.012
FSH		0.500		0.034		0.572		0.575	
	TF		0.080		0.005		0.091		0.092
	GN		0.081		0.006		0.093		0.093
	GL		0.037		0.002		0.042		0.042
	SN		0.274		0.019		0.313		0.315
	LS		0.028		0.002		0.033		0.033

two linear programming functions that were solved simultaneously to determine the point that best satisfied the two objectives. To achieve the first objective the linear equation was formulated as (Eq. (3)):

$$\sum_j \frac{w_j x_{ij}}{R_i^{\max}} = P_1 + d_1^+ - d_1^- \qquad (3)$$

where P_1 is the desired level of conflict and d_1^+ and d_1^- are deviational variables. The deviational variables allowed the possibility of not meeting the desired level exactly. The positive deviational variable indicates that the target has been exceeded while the negative deviational variable indicates that the target has not been exceeded. The left hand side is the summation of all habitats and human activities identified as contributing to conflicts in a particular conflict location. The weighted values of individual habitats and human activities $(w_j x_{ij})$ were divided by $R_i^{\max}$ (the highest overall score from present conflict analysis) to get standardized scores for the linear equation. To achieve the second objective the linear equation was formulated as (Eq. (4)):

$$\sum_j A_{ij} = P_2 + d_2^+ - d_2^- \qquad (4)$$

where the left hand side is the sum of total areas required by individual competing activities $j (j = 1, 2, \ldots, n)$ with respect conflict location $i (i = 1, 2, \ldots, n)$ and P_2 is total available for allocation; d_2^+ is the amount by which the area allocated to conflicting activities exceeded the target P_2 and d_2^- is the amount by which the total area to be allocated is less than that of the target value. Combining Eqs. (3) and (4) to achieve the two objectives simultaneously the 0–1 IGP was formulated as follows (Eq. (5)):

$$\text{Min } d_1^+ + d_1^- + d_2^+ + d_2^- \qquad (5)$$

Subject to

$$\sum_j \frac{w_j x_{ij}}{R_i^{\max}} = P_1 + d_1^+ - d_1^-$$

$$\sum_j A_{ij} = P_2 + d_2^+ - d_2^-$$

$$j_i = 1 \text{ or } 0$$

$$j_i = 1$$

$$j_{i1} + j_{i2} \le 1 \quad (j_{i1} \ne j_{i2})$$

$$d_2^+ = 0$$

where j_i is the 0–1 variable (human activity) in conflict location i; $j_i = 1$ when activity j is selected in conflict location i and $j_i = 0$ otherwise; j_{i1} and j_{i2} are mutually exclusive activities related to incompatible human activities j_1 and j_2 and $d_2^+ = 0$ ensures that the total area available for allocation is not exceeded. The combined linear equations selects human activities simultaneously on the basis of their contributions to the overall conflict score subject to a set of constraints imposed. To allocate a human activity a particular conflict area four elements were considered: 1) the activity's

Table 4
Table showing qualitative rankings for different levels of conflict.

Standardized conflict scores (R_i')	Rankings of conflict locations i
0–0.2	Lowest
0.21–0.4	Low
0.41–0.6	Moderate
0.61–0.8	High
0.81–1	Highest

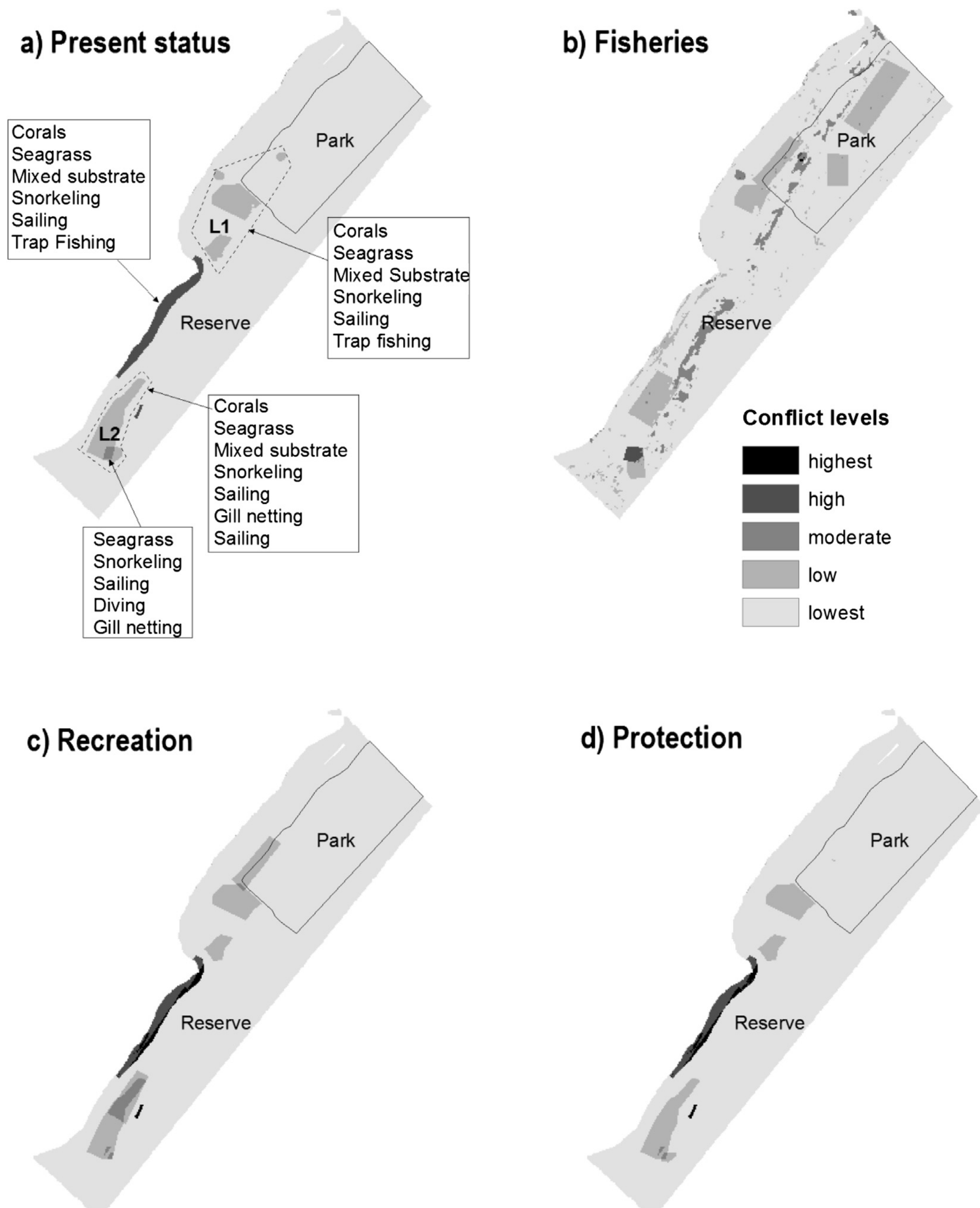

Fig. 3. Map output showing conflict levels under present use (a) and three management scenarios: (b) Fisheries; (c) Recreation and (d) Protection.

conflict coefficient; 2) the activity's spatial requirement; 3) compatibility with other activities; and 4) impact on habitats. Activities that impacted less of the habitats, those that had lower conflict coefficients and required less space, were likely to be allocated spaces within a conflict location. To achieve the objective of reducing conflicts to the lowest conflict level as defined in the pre-planning stage, P_1 was set at 0.2, which corresponds to the lowest conflict level (Table 4).

3. Results

3.1. Present and future conflicts

The results of weighting indicate that Fisheries with a weight of 0.5 was regarded as the most important coastal use in contributing to present conflicts, followed by beach activities (0.198), water recreation (0.166), sea access (0.093) and habitat protection (0.043) (Table 3). The very low relative weight assigned to habitat protection reflects the view that these do not necessarily cause conflicts but provide opportunities for different uses that result in conflicts. The coral reef habitats attract a higher level of conflict than other habitats (Table 3).

Spatial conflicts were ranked into 5 levels of criticality from the lowest to the highest (Table 4). The locations of the 5 conflict levels were evaluated using GIS operations to determine the spatial extents and human activities which contributed to conflicts in respective conflict locations. Under the present status of management the analysis of conflicts shows that over 90% of the study area (38.08 km^2) is still under lowest conflicts (Fig 3a). Locations of lowest conflicts were characterized by single or non-conflicting activities. Low conflicts covered 5.7% of the study area, occurring in four different locations that were clustered as L1 and L2 (Fig 3a). Low conflicts areas coincided with areas of coral reef, mixed substrate and seagrass beds habitats. Four incompatible activities (snorkeling, sailing, gillnetting and trap) were responsible for the conflicts in L1 and L2. Moderate conflicts covered 0.1% of the study area in locations associated with seagrass beds. Conflicting activities in moderate conflict areas included diving, snorkeling, sailing and gill netting. Locations of high conflicts covered 2.3% and were found in seagrass beds and mixed substrate habitats with beach seining contributing to the highest score in this location. Under the present management there were no locations of the highest conflict ranking.

We also assessed how changing present management objectives will change conflict outcomes. Three potential management objectives of increased use of the coastal area for: 1) fisheries; 2) recreation; and 3) protection were considered. The results of spatial MCDA depict changes in locations and extent of different conflict levels relative to present status (Fig. 3b–d).

Increased fisheries activities will potentially increase spatial extents of low, moderate and highest conflicts (Fig. 3b). The total area under low conflict will increase by 2.6 km^2. This increase will occur in areas of seagrass beds, corals reefs and beach habitats. In the seagrass beds beach seining will be competing with preservation of seagrass beds. Gillnetting will be competing with diving and snorkelling within coral reef areas while on the beach, fish landing sites will be competing for space with boat operators, curio sellers and turtle nesting sites. The spatial extent of moderate conflicts will increase by 1.4 km^2 in areas of coral reef where trap fishing, gill netting and gleaning are practised. The highest level of conflict which does not exist in the present status will emerge taking 0.01 km^2 of the study area. The total area under high conflict will reduce by 0.7 km^2 and shift from the present location in the intertidal areas to coral reef areas. Under the fisheries scenario more intense conflicts will shift to coral reef areas. The shift will change present lowest conflict levels to low and moderate conflict levels.

Increased use the coastal area for recreation will also result in spatial increases of low, moderate and highest conflicts by 0.2, 0.3 and 0.3 km^2 respectively (Fig. 3c). Locations of low conflict will coincide with areas presently used for trap fishing, gill netting, sailing and jet skiing in the seagrass bed habitat. Moderate conflicts will increase in areas used for sailing, wind surfing and trap fishing which are presently under low conflicts. Highest conflicts will displace high conflicts leading to a reduction in the total area under high conflict to 0.4 km^2. Highest conflict will result from overlaps between sailing, sea access areas and beach seining.

Under the protection scenario (Fig. 3d), lowest and highest levels of conflicts will increase by 0.1 and 0.3 km^2 respectively. Highest conflict will be found in the same location, similar to the recreation scenario. There will be reductions in the spatial extents by 0.1, 0.04 and 0.3 $km^2$for low, moderate and high conflict locations respectively but the locations will be similar to the recreation scenario.

3.2. Spatial allocations to reduce present conflicts

For purposes of allocation, conflict areas were clustered into 6 conflict zones with: 3 zones of low conflict, L1, L2 and L3; one zone of moderate conflict M1; and two zones of high conflict H1 and H2 (Fig. 4a). Each zone was evaluated to determine the human activities in respective zones. These human activities were the variables used in the optimization equations that were run for each zone. For each zone therefore, an optimal allocation was achieved by solving the integer goal equation (Eq. (5)) with $P_1 = 0.2$ (corresponding to lowest conflict level) and P_2 equal to the total area to be allocated to competing human activities in each zone. The 0–1 integer goal equation selected activities for a particular conflict zone based on their relative contribution to conflicts in that zone such that higher the conflict coefficient for an activity the more it will contribute to the overall conflict score and hence less likely to be selected. Fig. 4b shows results of the optimization with activities that were allocated different conflict zones. Reducing conflicts to the lowest level requires that: snorkeling and sailing are removed from L1; snorkeling, diving and sailing are removed from L2; diving, sailing and jetskiing are removed from L3; sailing, diving, snorkeling, diving and sailing area removed from M1; beach seining, moorings and inshore recreation are removed from H1; and sailing and wind surfing are removed from H2.

4. Discussion

Resolving coastal conflicts necessitates balancing environmental protection and human interests (Vallega, 1999, 2005). One way of achieving this is through impartial allocations to separate conflicting uses and protection to specific areas. On the Kenyan coast, MSP was used to create a proposed allocation plan that was based on agreed conflict resolution objectives and input from government agencies and stakeholder groups.

This study demonstrates that the MSP approach can be applied in coastal areas to allocate human activities in marine spaces where conflicts are already well-known and specified (Douvere and Ehler, 2008; Ehler and Douvere, 2009). The limitation in the MSP framework however arises from the lack of tools to implement various steps (Foley et al., 2010; White et al., 2012). We employed GIS, MCDA and optimization tools to implement the critical steps in MSP. These tools provide a straightforward method to identify and visualise conflicts and allocate space and, therefore, a way to arbitrate between competing human activities. They enable the incorporation of needs and preferences of stakeholders into decision-making (Ehler and Douvere, 2009) and can therefore help decision makers in qualitatively and quantitatively describing conflicts. In the context of conflict management MSP addresses some of the key elements required: 1) information development and analysis; 2) conflict assessment (where are the conflicts and what are the sources); and 3) procedural decision-making (deciding upon the process for addressing conflict). The MSP approach is therefore useful in resolving spatial conflicts in coastal areas and integrating conflicting objectives in a decision framework.

Apart from minimizing existing conflicts, it has been shown that MSP can also be used as a decision support tool that allows the assessment of the relative changes in conflict outcome with changes in management actions. Scenario analysis provides a relatively straightforward way to account for future uncertainties in conflicts. In this study, scenarios were developed to help inform managers about the potential consequences of decisions regarding use of space and resources. Implementing sector objectives, such as to increase fishing activity, recreation or protection, may potentially result in new conflict patterns. This reveals the need for joint planning between the all relevant sectors to reduce future conflicts.

Stakeholder participation is essential in resolving coastal conflicts. The MSP framework allows for the inclusion of stakeholders at different stages of the conflict resolution process (Ehler and Douvere, 2009). We went beyond the regular stakeholder consultation process and directly engaged competing users in a series of formal and informal meetings. Competing users were involved in identifying and completing the list of primary stakeholders. They were also involved in the field mapping exercises, setting up of conflict objectives and assigning weights of importance to different activities. The participation of stakeholders at different steps

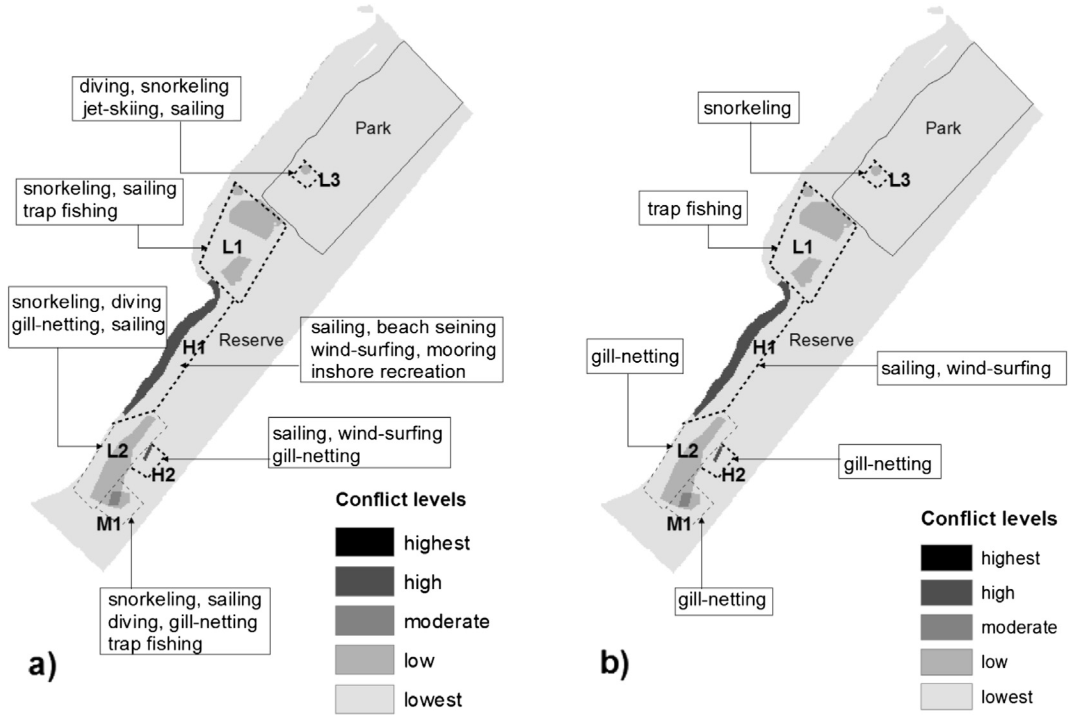

Fig. 4. a) Map showing conflicting actives in different conflict locations; b) map showing proposed allocation plan that will reduce conflicts to lowest levels.

created transparency and the visual nature of the GIS-MCDA approach allowed stakeholders to see how their interests and values were represented in the decision process. It also allowed the decision maker and stakeholders to agree on what solutions are feasible allocation options. The willingness of different users to be included in the conflict resolution process made it much easier to collect spatial data about their use areas (Table 1). The MMNP&R has had long standing user conflicts and the users themselves have been seeking a solution to the spatial allocation problems. These strong unresolved conflicts between different user groups motivated a willingness to join the deliberative process. None of the user groups was willing to be left out of the planning process because they perceived it as a process important to their livelihood. Furthermore many user groups felt that the MSP as outlined in the initial phases of the planning could potentially enhance collaboration and trust between stakeholders and improve mutual learning.

Internationally, the basic elements of MSP, as described above, have been applied over a huge range of spatial scales, from individual bays within a single jurisdiction (Dalton et al., 2010) to subcontinental spans (e.g. Álvarez-Romero et al., 2013). Within that range, marine spatial planning approaches have been applied to differing situations, for instance identifying and resolving conflict at the geopolitical level (Suárez de Vivero and Rodríguez Mateos, 2012), or implementing representative no-take reserves within Australia's Great Barrier Reef Marine Park (Fernandes et al., 2005). All of these have used in some measure the same toolbox (GIS, quantifying conflict levels, optimization tools), but the take up of MSP internationally has been relatively slow (Álvarez-Romero et al., 2013) in spite of published and well described methods (e.g. Ehler and Douvere, 2009; Gilliland and Laffoley, 2008; Malczewski, 1999; Malczewski et al., 1997) and the increasing availability of these tools. Not least, this may reflect the level of stakeholder engagement required to understand the quantitatively derived, but arcane outputs from the various software tools and see their relevance to the everyday user context. The process of introducing no-take areas to protect at least 20% of 70 distinct bioregions within the Great Barrier Reef Marine Park required extensive and intensive consultation over more than six years (Day et al., 2003), and the biggest single problem was that community understanding of the threats to coral reefs was poor (Fernandes et al., 2005): "…introducing a solution without clarifying the problem would not work" (ibid P. 1738). This demonstrates that successful implementation of MSP will depend on effective engagement and communication with all stakeholders.

5. Conclusion

It is probable that competition for increasingly scarce resources in the years to come will create conflicts between ranges of different actors in coastal regions such as those in Kenya. As such the development of conflict management mechanisms adaptable to the particularities of these conflicts should be developed. The MSP framework applied here provides a useful tool for analysing, qualitatively and quantitatively, conflicts over coastal resource use and facilitating informed decisions when exploring interactions among resource users. Its significance for the future of coastal zone management is to provide the needed platform for participatory involvement in order to minimize user conflicts. We have illustrated that the MSP framework can be used in managing, and potentially resolving, conflicts in coastal areas because it allows competing users to: 1) specify their concerns and interests that can directly mapped; 2) elicit preferences (using weights); 3) compute a ranking for conflict hotspots and display as maps); 4) predict future conflicts; and 5) allocate spaces to competing users. It is therefore a useful tool for coastal managers and stakeholders for decision-making in coastal areas where conflicts are known to exist. This study can be considered as a first-step towards developing a multiple coastal area use plan in Kenya. However, future marine and coastal use plans will require more information on emerging uses such as oil and gas exploration areas, port development, and communication infrastructure development such as fibre optic cables. The feasibility of applying this methodology in other coastal areas will depend on a number of important factors such as stakeholder involvement, availability of data and knowledge base.

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