AMBIO 2014, 43:1006–1019
DOI 10.1007/s13280-013-0465-8

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

REPORT

Intertidal Zone Management in the Western Indian Ocean: Assessing Current Status and Future Possibilities Using Expert Opinions

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Received: 5 December 2012 / Revised: 13 May 2013 / Accepted: 15 October 2013 / Published online: 28 December 2013

Abstract This expert opinion study examined the current status of the intertidal zone in the Western Indian Ocean (WIO) and ranked and discussed future management approaches. Information was gathered from scientists, practitioners, and managers active in the WIO region through a questionnaire and a workshop. The experts stated that the productive intertidal environment is highly valuable for reasons such as recreation, erosion protection, and provision of edible invertebrates and fish. Several anthropogenic pressures were identified, including pollution, harbor activities, overexploitation, and climate change. The experts considered the WIO intertidal zone as generally understudied, undermanaged, and with poor or no monitoring. The most important management strategies according to the expert opinions are to develop and involve local people in integrated coastal zone management (ICZM), to increase knowledge on species–environment relationships, and to develop awareness campaigns and education programs. To improve coastal environmental management and conservation, we argue that the intertidal zone should be treated as one organizational management unit within the larger framework of ICZM.

Keywords Expert opinions · Ecosystem function · Integrated coastal zone management (ICZM) · Closures · Environmental monitoring · Ecosystem-based management

INTRODUCTION

The land-to-sea continuum is an emerging frontier in conservation biology, pointing out the ineffectiveness of separating land and sea into different components (Sloan et al. 2007). The intertidal zone constitutes the coastal environment where land and sea meet, i.e., the area between extreme high water springs (EHWSs) and extreme low water springs (ELWSs, Fig. 1). This zone provides numerous ecosystem goods and services; however, most of them are poorly understood (Barbier et al. 2011). In addition, ecosystems located in the intertidal zone are experiencing degradation and an accelerating loss of biodiversity, which might potentially affect ecosystem goods and services and human well-being, although such knowledge is still largely unknown (Balmford and Bond 2005; Lotze et al. 2006; Worm et al. 2006).

The Western Indian Ocean (WIO) with its extensive and dynamic intertidal zone supports a wide diversity of habitats such as mangroves, seagrass meadows, sandy beaches, rocky shores, and shallow corals. The large variety of habitats, high productivity, and accessibility attract many resource users using the area in multiple ways; this, however, creates competition for space and resources. The variety of uses of the intertidal zone must be coordinated, for example, among small-scale fisheries, harvesting of natural construction materials, tourism, and the large number of female users, e.g., seaweed farmers and invertebrate harvesters (Jiddawi and Öhman 2002; de la Torre-Castro and Rönnbäck 2004; Nordlund et al. 2010; Fröcklin et al. 2012). The open-access character of the intertidal zone and the multiple human uses create several anthropogenic pressures which are threatening the intertidal environment (Halpern et al. 2007).

Threats are multifaceted and two-directional, coming from both land and ocean. Some examples are runoff,

Electronic supplementary material The online version of this article (doi:10.1007/s13280-013-0465-8) contains supplementary material, which is available to authorized users.

Fig. 1 An intertidal zone covered with seagrass during low spring tide (tidal range 4 m, diurnal) in Zanzibar, Tanzania. Photo: Lina Mtwana Nordlund

pollution, and overexploitation of natural resources in different ecosystems leading to resource depletion and habitat degradation (Rocliffe 2010).

There is a clear lack of research in the WIO concerning habitats associated with the intertidal zone (e.g., seagrass meadows, very shallow corals, unvegetated bottoms, and sandy shores). Only a few distinct geographical areas in the WIO, for example, Chwaka Bay in Zanzibar and Gazi Bay in Kenya, are well researched (e.g., Conand 2002; Gullström et al. 2002; Erlandsson et al. 2008; de la Torre-Castro and Lyimo 2012). In some areas, studies of coastal geomorphology have been undertaken (see, e.g., Kairu and Nyandwi 2000). At the species level, a number of inventories have been performed, primarily focusing on certain groups of invertebrates (gastropods and echinoderms), vegetation (mangroves, seagrasses, and marine algae), and birds (Conand and Muthiga 2007; Muthiga and Kawaka 2010; Richmond 2011).

The high human dependence on coastal resources and the drive for development create a major challenge for effective resource management and conservation planning of the land–sea interface (Sloan et al. 2007). This is especially challenging with intertidal zones in the WIO, where a large part of the human population lives below the poverty line. In the WIO, low income has been reported, for example, in small-scale fisheries (de la Torre-Castro and Rönnbäck 2004; Cinner 2009; Nordlund et al. 2010) and seaweed farming activities (Fröcklin et al. 2012).

In addition to the difficult issue of balancing development and conservation is the challenge of linking science, management, and end users. Research that intends to inform policy makers and managers often fails due to communication and awareness issues between different communities (e.g., scientist's scientific knowledge vs. manager's pragmatic approaches). Moreover, policy makers and managers may not be updated and advised by the best science (Lauber et al. 2011). There is clearly a need to overcome such differences to produce better management results. Although the accessibility and broad use of the intertidal zone can create great pressure on ecosystems and

lead to conflicts among users, it might also result in more effective protection of the area, due to familiarity and closeness compared to, e.g., conserving the deep sea (Vincent 2011).

The multitude of threats to the intertidal zone, together with the high anthropogenic value, calls for proactive management combined with effective conservation approaches (Sloan et al. 2007). In this matter, inclusion of the people and their needs together with a serious focus on sustainable resource use would be needed. Furthermore, the diffuse and shifting boundaries of the intertidal zone can complicate decision making since management jurisdiction areas are difficult to establish.

The aim of this study was to advance our understanding of the current status of the intertidal zone in the WIO. Due to scarce research on the intertidal zone, experts' opinions were used to address, describe, and discuss problems, values, and potential management options of the intertidal zone. Data were gathered from (1) a questionnaire, and (2) a workshop that brought together scientists, practitioners, and managers active in the WIO region. Expert opinions are commonly used in conservation assessments (e.g., by the EU commission for evaluations under the Seventh Framework Programme) and in environmental modeling (e.g., Krueger et al. 2012) to fill data gaps. We use the expert definition as proposed by Krueger et al. (2012), namely, "an expert can be anyone with relevant and extensive or in-depth experience in relation to a topic of interest". Experts are thus here defined as managers, practitioners, and researchers active in the WIO region working with (1) questions related to the natural or social environment in any part of the intertidal zone, and/or (2) questions relevant to the intertidal zone (e.g., pollution). In this study, we surveyed the current knowledge and management strategies of the intertidal zone among the above experts, and assessed the confidence, feasibility, and importance of potential management strategies. We also analyzed, using multivariate methods, how close the experts' opinions were related in terms of area of work/interest as well as management strategy score. Understanding the current status of intertidal management and identifying conservation/management options that are adaptive and involve resource users can provide researchers, managers, and policy makers with clear and concrete suggestions that may improve the management of the intertidal zone. Specifically, the following questions about the intertidal zone of the WIO were addressed by consulting WIO experts: (1) Which are the important habitats and their associated values in the intertidal zone? (2) Which are the current and potential threats to this zone? (3) What is the current status of research, monitoring, and management? (4) Which are the future needs for effective management? and (5) Which management strategies are the most important, feasible, and confidently conducted?

FOCUS REGION

The WIO region refers to the African coastal states of Somalia, Kenya, Tanzania, Mozambique, and South Africa together with the Indian Ocean island states of Comoros, Madagascar, Mauritius, the Seychelles, and France represented by the islands of Mayotte, La Reunion, and Eparses Islands (UNEP 2007; UNEP/Nairobi Convention Secretariat and WIOMSA 2009; Fig. 2). The region covers tropical and subtropical conditions. The region has been well described by Coughanowr et al. (1995), but during the last two decades, the population has greatly increased and is now more widely distributed, which is increasing the pressure on the coastal zone and hence the intertidal zone (Shi and Singh 2003).

In the WIO, the tidal range is 0.4–7 m depending on the geographical location; in general, countries eastward of the region have larger tidal ranges, and in bays and creeks the range can be very large. The tides are predominantly semidiurnal, which means that the area experiences two low tides and two high tides per day. The intertidal zone is located between the EHWS tide and the ELWS tide. The environment is constantly changing due to the submersion of habitats during high tide and exposure during low tide. This creates extreme environmental conditions with regard to, e.g., temperature, salinity, and wave action.

MATERIALS AND METHODS

The empirical data for the present study were based on "experts' opinions" (see, e.g., Krueger et al. 2012; Martin et al. 2012). The expert opinions were collected during the 7th Western Indian Ocean Marine Science Association (WIOMSA) Scientific Symposium (24–29 October, 2011) held in Mombasa, Kenya, which provided the opportunity to meet a large group of scientists and practitioners active in the WIO region. During the symposium, two main ways to gather the opinions were used, first a questionnaire and second a workshop. The workshop entitled "Managing the intertidal zone?" was organized on the last day of the WIOMSA symposium to discuss WIO intertidal zone matters. The approximate number of participants to the conference was 500 and from those, 25 attended the workshop. All information was handwritten by a secretary and parts were also audio recorded as backup.

The questionnaire (Appendix S1 in the supplementary material) consisted of two parts; the first part was designed

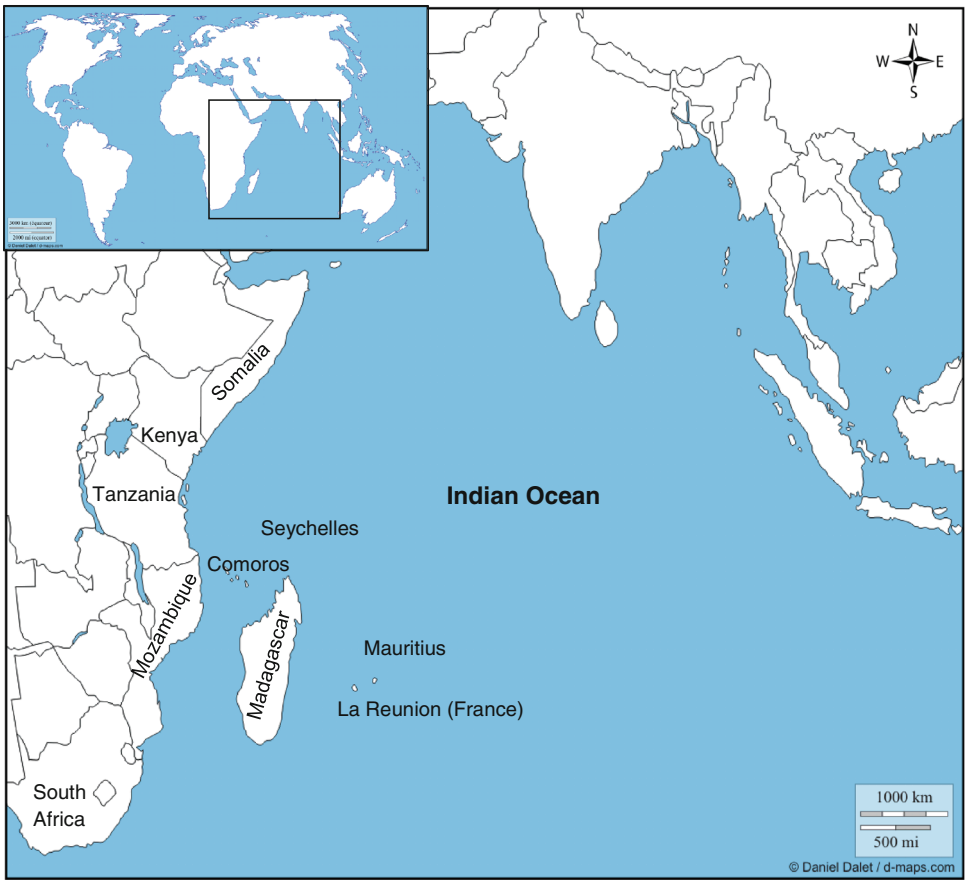

Fig. 2 Map of the Indian Ocean (*source* www.d-maps.com). The WIO mainland coast is 13 000 km long and stretches from Somalia to South Africa and the island states have a coastline of 6360 km (UNEP/Nairobi Convention Secretariat and WIOMSA 2009)

to gather the current status and knowledge about the intertidal zone, its values, habitats, threats, ongoing monitoring and management, awareness, and prioritization. The second part of the questionnaire comprised closed questions to capture the level of support for different management strategies. The support was measured using a scoring system (1–4, where 1 = low and 4 = high; 0 = I do not know) for confidence, feasibility, and importance for each of the suggested management strategies. The suggested management strategies, based on the ideas exposed in Nordlund et al. (2011), were chosen based on the circumstances of the intertidal zone, i.e., whether there is dense population, overexploitation, lack of research, lack of knowledge, etc., which calls for different management strategies and stresses the need to balance between resource use and conservation. The management suggestions were presented as explorative tools to test management in the intertidal zone as suggested by the adaptive management approach (Armitage et al. 2007). The management strategies shown in Table 1 were used to frame the latter part of the workshop discussions and to formulate the closed questions in the questionnaire (see Appendix S1 in the supplementary material for questionnaire and a more detailed explanation about the approaches). Formal institutions were also discussed during the workshop.

Statistical Analyses

Multivariate analysis using the PRIMER software package (version 6) was used to assess (a) how respondents' areas of interest were related to other respondents, and (b) respondents' opinions about different management approaches in relation to other respondents. Patterns of similarities were visualized using non-parametric multidimensional scaling (nMDS) based on the Bray–Curtis similarities matrix calculated using raw data.

RESULTS

The Questionnaire's Respondents and Workshop Participants

Out of the 53 questionnaire respondents, 58 % were female and 42 % were male. They classified themselves as managers (9.5 %), professors (11 %), PhDs (26.5 %), PhD

Table 1 Management strategies presented to experts to frame workshop discussions and formulate the closed questions. Explanation of strategy if needed, and where applicable a summary of experts' comments from workshop discussion

Management strategy; *brief explanation*. Summary of experts' comments from workshop discussion
(i) **Awareness campaigns and education program;** *could be used to inform the community about different issues and threats to the intertidal zone*
(ii) **Strengthening and encouraging the use of traditional and local ecological knowledge (LEK);** *e.g., encouraging viable and useful knowledge being passed from generation to generation*
(iii) **Informal institutions and traditional practices**; *norms and practices not written in formal laws or documents*
(iv) **Laws against trade of key species and education for tourists**
(v) **By-laws;** *designed for specific problems at local scales.* Bottom-up approach. Communication of by-laws is important, but migrants make this matter difficult. Use when the law needs to be enacted at local level before being tried nationally, or to enforce the implementation of NTZ and temporal closures at local levels. Potentially more acceptability/legitimacy to rules, leading to higher compliance and in turn increased protection. Should be participatory and cooperative to avoid dysfunctional top-down steering
(vi) **Developing integrated coastal zone management plans involving local people**; *the users (local people) should be involved in the whole process (participatory approaches, co-management).* Useful since it considers all aspects of the coastal zone, involving local people and stakeholders to make them aware of the developing changes. Should be done at national level and involve all stakeholders to solve the conflict of interest and find solutions. Will increase understanding of the cycle of all species, which is important baseline information needed in successful conservation of the intertidal zone. Developing alternative livelihood options would be a very important aspect of successful ICZM
(vii) **Conduct research on important species and their relation to intertidal ecosystems**; *including basic research such as species inventories of areas with mixed* densities of seagrass
(viii) **Establish size limits for the organisms harvested/fished**; *size limits could be applied to the most popular and commercial species such as mangrove and clams*. Scientific knowledge is needed to back up appropriate sizes of, e.g., reproductive maturity. To be successful, compliance and monitoring are important and there must be laws to enforce and facilitate the process. A need for information and education for successful implementation. Useful, but the challenges are huge in terms of research needs and that size limits vary among species. Could work in combination with closures, gear restrictions, or be site specific and enforced by beach recorders (monitoring agents, see de la Torre-Castro 2006). Potential outcome would be to create a path for sustainable use, allowing people to access resources. Benefits might be detained due to slow recovery of species
(ix) **Habitat maps and remote sensing**; *should be used to show coverage and distribution of habitats, detect changes with long-term series of satellite images or aerial photos.* Managers need to understand their resources and the above are good tools for monitoring, creation of baseline data, etc., but do not give straight solutions for complex management problems
(x) **Temporal and/or spatial closures**; *e.g., known spawning grounds.* Highly necessary, especially for endangered organisms, during breeding seasons and in particular localities, and favorable for the environment. Great need for research in order to position the closures correctly. Success could depend on the organism and might only be possible for a few species. Clear information to the community about the reasons behind the closure was considered critical. During open seasons, there should be adequate control
(xi) **Establish no-take zones in highly degraded areas together with the community**. Good idea since it helps to improve degraded areas, but non-degraded areas should also be considered and it is important to insure that pressure is not just shifted to another area. Site-specific research is needed to assure appropriate sizes, relevant to species targeted, and placed in suitable locations, such as breeding sites, non-polluted sites, and sites allowing connectivity. A need for long-term establishments/studies, and collaboration with local people is essential. Can allow for recovery of degraded environments, but might increase the pressure on neighboring zones
(xii) **Small enclosures to boost larval production**; *create aggregations*
(xiii) **Integrated mariculture**; *increase the availability of edible animal protein or to increase the production of mariculture species*
(xiv) **Formal institutions**; Importance to use a sound research base, consult the right expertise for decision making. Have a large coverage and facilitate communication. Important to be aware of potential top-down management. Applicable on regional to provincial to national level. Helps management coordination, uniformity, and effectiveness. This approach often takes time and that unilateral top-down decisions can be easily rejected

students (32 %), and MSc students (21 %). It is important to point out that many respondents in the two last categories have several years of work experience with management and/or conservation.

The respondents' areas of work/interest were in decreasing order fisheries, management, conservation, climate change, coral reefs, biodiversity, social-ecological systems, MPAs, mangrove, seagrass, livelihoods (>10 persons), socio-economic (<10 persons), aquaculture, connectivity, invertebrates, education, genetics, adaptation, pollution, resilience, policy making, oceanography, forestry, vulnerability, chemistry, remote sensing, health, politics, policy, food webs, ecosystem services, landscape ecology, and demography. Each respondent had the possibility to choose one or more areas of interest. The MDS plot shows how the respondents' areas of interest were related to each other (Fig. 3).

During the workshop, all countries in the WIO region had a representative (except Somalia). The workshop participants were all attending the symposium and fulfilled the criteria to be considered as experts.

Intertidal Habitats and Values

The experts identified that the intertidal zone in the WIO hosts a wide range of important habitats, and the commonly mentioned ones were mangroves, seagrass meadows, coral reefs (surprising since coral reefs are normally subtidal), rocky shores, sandy areas, and reef flats. Table 2 shows the complete list of intertidal habitats mentioned. The experts also mentioned that the intertidal zone attracts many animal species, including invertebrates, fishes, birds, and reptiles as well as several migrating animal species. Furthermore, the intertidal zone was considered highly valuable for reasons such as tourism and recreation, the presence of seagrasses and mangroves improving water quality and protecting the shoreline, the presence of many edible invertebrates and fish, timber, nutrient cycling, and diversity maintenance. All values mentioned by the respondents are summarized in Table 2. Furthermore, it was stated that the intertidal zone with its easy access is used basically by all people—men, women, children, tourists, and fishers. In summary, the opinions revealed a heterogeneous "landscape" with a "high value" for humans.

Current and Potential Threats to the Intertidal Zone

A wide range of threats to the intertidal ecosystems in WIO was identified by the experts in the questionnaire and during the workshop encompassing all scales, from a global scale such as climate change to a local scale such as sand mining. In addition, they expressed a feeling that the amount of threats were overwhelming and difficult to manage. Several destructive fishing methods were mentioned such as "damage to seagrass beds from seine netting" and "drag-nets" or other destructive activities such as "mangrove clearance for aquaculture or rice farming". Another comment was "lack of education and poverty as well as population growth", thus including social aspects. The most commonly mentioned threats were pollution, overharvesting, habitat destruction, climate change, and overfishing (see Table 2 for all threats mentioned by the respondents).

Current Research, Monitoring, and Management

During the workshop, we asked about existing and available research and management related to the intertidal zone in the WIO region and overall there seems to be a very limited amount of peer-reviewed research dealing with the intertidal zone. We encouraged the participants to mention all research concerning the intertidal zone that they were aware of. Thus, there was a clear consensus among the workshop participants as well as the questionnaire respondents on the lack of research and management efforts in the intertidal zone compared to other coastal environments. Monitoring projects were mentioned as scarce and in many cases absent, and management attention was considered very low in most countries. Mangroves followed by seagrass meadows were viewed as the habitats where most research has been conducted, although participants clearly expressed that these habitats are still far behind, for example, coral reefs in subtidal areas. It was highlighted that there is a substantial lack of research in remote areas such as parts of Mozambique and Madagascar, and Pemba Island (Zanzibar, Tanzania), mainly due to lack of infrastructure and access difficulties. Furthermore, it was stated that "there is a need for more research on location, dynamics and economic values" of the intertidal zone. The monitoring efforts mentioned in the questionnaire and during the workshop as past or ongoing were some seagrass monitoring (through, e.g., SeagrassNet, www.seagrassnet.org), some baseline monitoring of seagrasses and mangroves in Kenya, turtle nesting, temporary fish closures, fish landing data, mangrove status by REDD (The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), and several of the habitats in Velondriake, Madagascar.

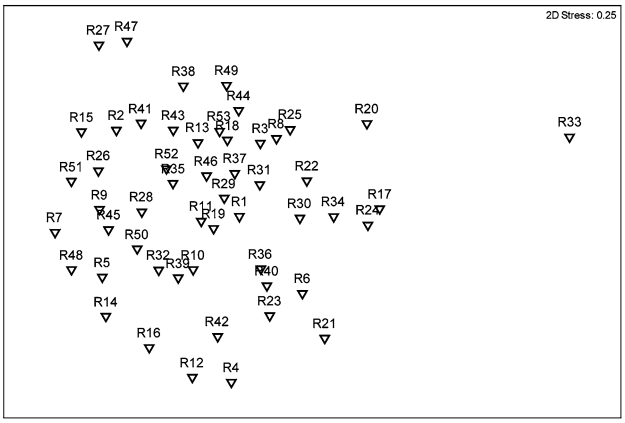

Fig. 3 Distance between respondents' area of work/interest. Each *triangle* in the MDS plot represents one expert's background. The scattered pattern implies that most experts have different areas of work/interest compared to the other respondents; the longer the distance between experts in the plot, the larger the difference in areas of work/interest

According to the experts, the intertidal zone lacks formal management (Table 3), which was also mentioned during the workshop. Stated reasons for this were that intertidal zone management is forgotten and/or not prioritized because there is no recognition of its importance. Gender aspects were mentioned as important factors too. The following quotes from the questionnaire illustrate these facts: "(The intertidal zone is) assumed to be less

Table 2 A summary of ecosystems/habitats, values, and threats of the intertidal zone in the WIO region identified by experts (interview forms and workshop). Listed in order of most mentioned in the interview form

Ecosystems/habitats	Values	Threats
Mangrove	Productive areas	Pollution
Seagrass	High food production/provider	Over harvesting
Coral reef	Highly productive area	Habitat destruction
Rocky shores/Cliffs	Protection of coastline	Climate change
Sand/Beach	Protection for land runoff	Overfishing
Reef flat	Protection from waves, storms, etc.	Erosion
Mudflats	Protection against erosion	Constructions
Estuaries	Accessible for seaweed farming	Destructive practice
Mollusk banks	Sediment stabilization	Eutrophication
Tidal pool	Fresh water retention	Agriculture
	Recreational area	Increasing human population
	Unique biodiversity	Sedimentation
	High biodiversity in small area	Mariculture
	Highly adaptive environment	Tourism
	Attracts tourism	Development
	Esthetical area	Oil spill
	A link in nature	Invasive species
	Carbon sink capacity	Mining
	Buffer zone	Mismanagement
	Infrastructure, e.g., ports	Oil and gas exploitation
	Supports activities to generate money	Poverty
	Cultural value	Storm
	Boat mooring area	
	Water nutrient regulation	
	Providing building material, e.g., shells, sand	
	Area for mariculture	
	Hatching grounds	
	Feeding grounds	
	Nursing grounds	
	Upstream chemical affluent sieve	
	Nice climate, e.g., sea breeze	

valuable compared to offshore fishing and many of the near shore activities are performed by women", and "There is mostly subsistence value of (intertidal) fisheries and little commercial value—even though this perception is generally not true".

Summing up, a clear majority of respondents think that the intertidal zone does not receive enough attention and one of the several reasons for that was stated to be "because it is an area that falls between research disciplines and it is not recognized as an important, productive and diverse area".

Future Needs of the Intertidal Zone

The experts informed both through the questionnaire and the workshop that the values of the intertidal zone are often unknown, due to, e.g., very little available data and research. In the questionnaire, a majority (86 %) said that there was not enough knowledge in general, but some stated that for a few habitats, e.g., mangroves, there is some knowledge. Status of knowledge was correlated with the level of development (e.g., South Africa probably has more knowledge). Seven percent were unsure and another 7 % believed that there is generally enough knowledge. Eighty-six percent of the experts also thought that there was not enough knowledge among government officials, while 10 % thought it was enough. Twenty percent thought that there was enough knowledge among managers, but still a majority were doubtful (56 %). Thirty-five percent thought that there was enough knowledge among researchers working in adjacent habitat, while 44 % did not agree, especially due to the strict specialization in research. Many experts (44 %) thought that there was enough local knowledge about the intertidal area, especially for people regularly using the areas, such as fishers, while 42 % thought that the local population does not have enough knowledge.

One comment was that "Since 'intertidal areas' are very heterogeneous and differ very much in structure, function and ecology, it is difficult to have 'enough knowledge' for anyone who has not seen all different types! The local population may in this respect probably have the best 'enough knowledge' about their local environment!" Several of the experts also expressed a lack of knowledge within adjacent research fields related to the intertidal zone as well as within management and/or conservation of the intertidal zone. Furthermore, it was stated that the intertidal zone has "low priority, because intertidal users are considered as a non-threat compared to other marine resource users". Moreover, in both the questionnaire and during the workshop, it was concluded that it is difficult to define the borders of the intertidal zone since the water is always moving, and the management often falls in between departments and government agencies, i.e., either focuses on land or on sea and the area in between often becomes excluded. Allocation of enough monetary resources was highlighted as problematic. Some experts stressed that projects often have to be done according to donors, ignoring the important aspects of thorough assessments before project establishment.

The experts listed a wide variety of aspects that need to be managed in the intertidal zone corresponding to the

Table 3 Examples of different statements given by experts in the interview form for constraints for management

Current constraints for better management in the Western Indian Ocean	
"Management is focused on 'sexier' ecosystems"	"The image of the intertidal is that it is degraded"
"Management plans are designed for known environmental problems"	"Low priority, because intertidal users are considered as a non-threat compared to other marine resource users"
"Intertidal zones are rarely targeted for particular management"	"Managers need 'borders', the intertidal becomes a moving target!"
"Intertidal zones are not included in management plans because they are mostly viewed as a wasteland"	"Important habitats within the intertidal zone, such as octopus reef flats, mangrove and seagrass do receive management attention"
"There is a need for more research on locations, dynamics and economic values of the intertidal area"	"Government should recognize the importance of the intertidal zone and ongoing activities"
"Sometimes it is classified as 'land' and sometimes it will be 'water'"	"More focus needed in the intertidal area management, and that there is a need for more funding for this area"
"Management plans often deal with one or two areas that can be found in the intertidal (e.g. seagrass meadows or mangroves) but not with a holistic approach"	"Today, too much money is wasted on badly designed and focused projects! Better planning is needed and money should be invested in good projects! This would probably mean that more money is needed in the end"
"I think the mangroves might be higher prioritized than other parts of the intertidal but compared to (Coral) reefs and fishing issues it's probably less prioritized"	"No there is not enough knowledge about intertidal areas and this is ubiquitous (everywhere) for the coastal seascape. I think there is a knowledge gap but it could be better managed with common sense alone—therefore it is probably not the lack of knowledge that is the biggest gap. It is a very complex situation and lack of management probably more often relates to governance and social equity rather than lack of knowledge on ecology etc".

threats mentioned (Table 2). Some of the aspects mentioned in need of attention and/or management were, e.g., extractive activities (e.g., sand mining and mangrove cutting), fisheries (finfish and invertebrates), development of the intertidal zone, destructive practices, pollution, eutrophication, erosion, aquaculture (e.g., seaweed farming), land runoff, and careless people. Education was considered a way to address problems and threats to the intertidal zone.

It was also pointed out that management plans are often developed according to already known environmental problems, but lack of knowledge in the intertidal zone hinders taking action. Furthermore, the authorities might not be aware of the importance and extensive use of the intertidal zone.

Level of Support for Different Management Approaches

The level of support for the suggested management approaches according to the questionnaire respondents, with regard to importance, was highest for the following strategies: "developing integrated coastal zone management plans involving local people", "conduct research on important species and their relation to intertidal ecosystems", and "awareness campaigns and education program", closely followed by "temporal and/or spatial closures" and "establish no-take zones in highly degraded areas together with the community" (Fig. 4; Table 4).

The highest proxy (confidence/importance) for realistic success of the proposed management strategy was for "conduct research on important species and their relation to intertidal ecosystems", "habitat maps and remote sensing", and "by-laws", closely followed by "strengthening and encouraging the use of traditional and local ecological knowledge", "awareness campaigns and education programs", and "laws against trade". The importance, feasibility, and confidence scores and proxy values are shown in Table 4.

The MDS ordination based on the similarity between the responses made by different experts shows that many respondents answer in a rather similar way, although a few respondents have different opinions (Fig. 5). During the workshop, the experts were divided into small groups (5–10 people) to discuss usefulness, applicability, potential outcomes, and further suggestions of seven of the suggested management approaches including formal institutions, the establishment of size limits for organisms, establishment of no-take zones (NTZ) in highly degraded areas, by-laws, developing integrated coastal zone management (ICZM) plans involving local people (participatory and co-management programs), temporal and/or spatial closures, and habitat maps and remote sensing (see Table 1 for main discussion outcome).

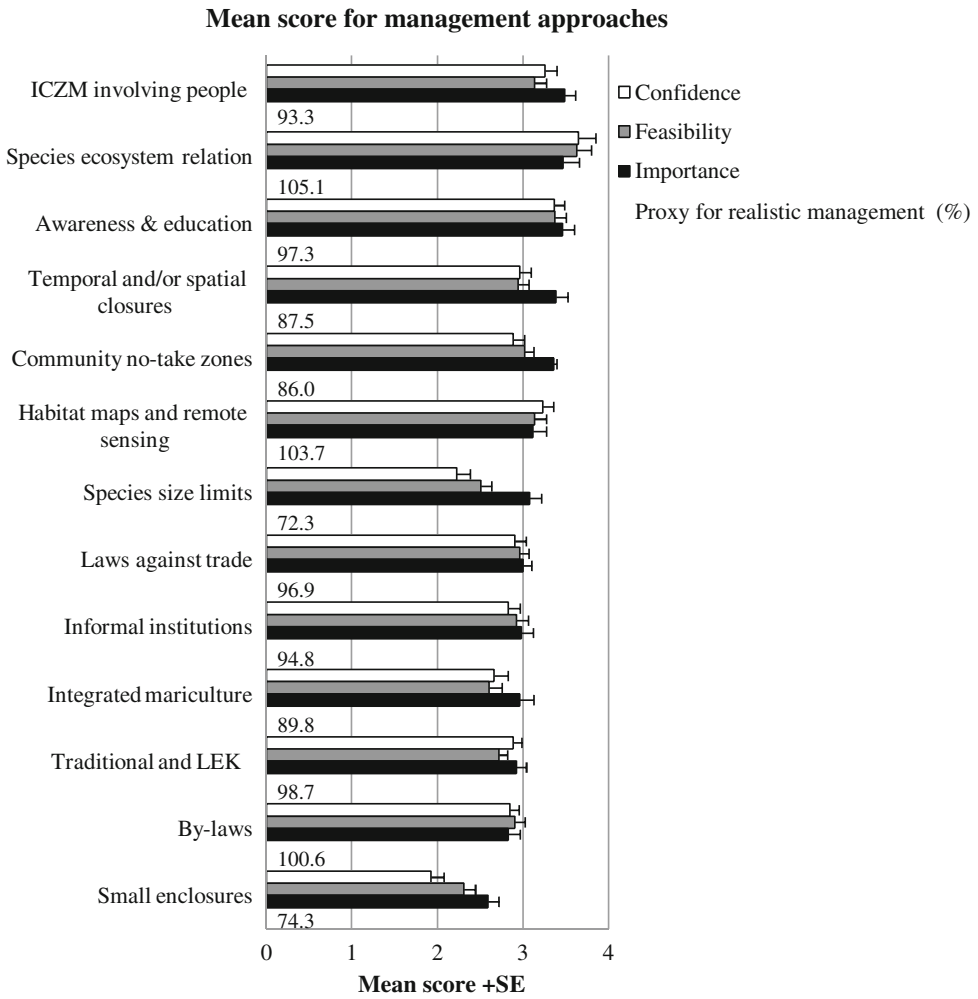

Fig. 4 Average score for management strategies; scores = 1–4, where 1 = low and 4 = high; 0 = I do not know. The proxy (confidence/importance) for realistic management is given below each bar set in percent. The figure is arranged according to the "importance" score

DISCUSSION

The outcomes of the questionnaire and the workshop show that the experts think that the intertidal zone in the WIO is generally understudied, undermanaged, and lacks monitoring; thus, basic research and continuous monitoring at the appropriate scales are needed. The intertidal zone was considered very rich in habitats, resources, and values. Interestingly, productive intertidal habitats in other parts of the world, such as lagoons, algal beds, and salt marshes, were not mentioned as the most important habitat by any of the respondents or during the discussions, which supports the idea that research and knowledge are lacking for many intertidal habitats in the WIO region. Awareness and education were considered as approaches of high importance, confidence, and feasibility; this is probably partly reflecting the lack of information and information sharing in the region and the need to enhance education of the general population for sustainability.

There were several threats identified in the study, and these threats may interact in complex ways and thus different combinations of impacts may affect the intertidal zone differently, especially since the threats are both land based and ocean based. Two globally important threats are overfishing (Anderson et al. 2011) and ocean acidification (Abbassi and Abbassi 2011), which may have severe impacts on intertidal ecosystems. Generally, the threats to the intertidal zone have major social, economic, and environmental concerns to the countries in the WIO region. Research may identify several additional threats than those mentioned in this study. Another problem seems to be that the intertidal zone deals with issues such as methodological and monitoring inconsistency.

We believe that one of the reasons why it is difficult to manage the intertidal zone in particular might be that it has easy and open access, everyone can use it, and can do so in so many different ways. This can raise conflicts over spatial use or resource preferences creating a "tragedy of

Table 4 A summary of the questionnaire scores for management strategies. The table shows average, median, and mode score for 13 management strategies; scores = 1–4, where 1 = low and 4 = high for confidence, feasibility, and importance. The proxy (confidence/importance) for realistic management is given below each approach

Strategy	Confidence	Feasibility	Importance
ICZM involving people			
Average	3.25	3.13	3.49
Median	3	3	4
Mode	4	3	4
Proxy	93.30 %		
Research: species ecosystem relation			
Average	3.65	3.63	3.47
Median	4	4	4
Mode	4	4	4
Proxy	105.10 %		
Awareness and education			
Average	3.37	3.37	3.46
Median	4	4	4
Mode	4	4	4
Proxy	97.30 %		
Temporal and/or spatial closures			
Average	2.96	2.94	3.38
Median	3	3	3.5
Mode	3	3	4
Proxy	87.50 %		
Community no-take zones			
Average	2.89	3.02	3.36
Median	3	3	4
Mode	3	3	4
Proxy	86 %		
Habitat maps and remote sensing			
Average	3.23	3.13	3.12
Median	3	3	3
Mode	4	4	4
Proxy	103.70 %		
Species size limits			
Average	2.22	2.51	3.08
Median	2	2	3
Mode	2	2	3
Proxy	72.30 %		
Laws against trade			
Average	2.91	2.96	3
Median	3	3	3
Mode	3	3	4
Proxy	96.90 %		
Informal institutions			
Average	2.83	2.92	2.98
Median	3	3	3
Mode	3	3	3
Proxy	94.80 %		
Integrated mariculture			
Average	2.66	2.6	2.96
Median	3	3	3
Mode	3	3	3
Proxy	89.80 %		
Traditional and LEK			
Average	2.89	2.72	2.92
Median	3	3	3
Mode	3 & 4	3	3
Proxy	98.70 %		
By-laws			
Average	2.85	2.9	2.83
Median	3	3	3
Mode	3 & 4	3 & 4	3
Proxy	100.60 %		
Small enclosures			
Average	1.92	2.31	2.59
Median	2	3	3
Mode	2	3	4
Proxy	74.30 %		

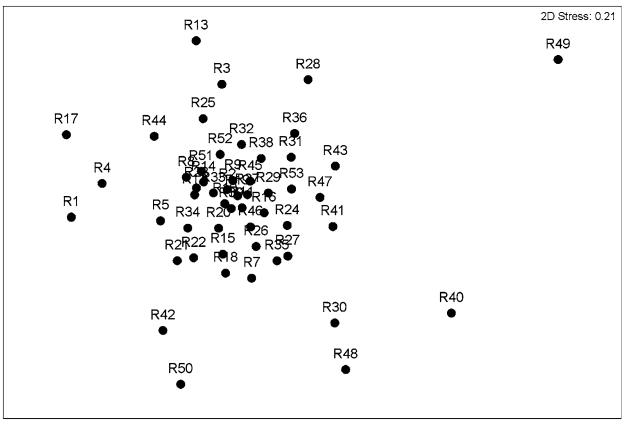

Fig. 5 MDS plot showing respondents' (R) answers on level of support for the different management strategies. Each *dot* represents one expert, and the assembly of *dots* in the *plot* implies that a great similarity of the experts' level of support was found, but that some outliers were also present, i.e., some experts scored level of support differently than most experts

the commons" situation (Hardin 1968). This calls for different management strategies of intertidal areas, which stresses the need to better balance resource use and conservation and the need to involve local institutions (e.g., National Research Council 2002; Brown 2003; Dietz et al. 2003).

There is a lack of legal and management instrument that can deal with the shifting boundaries as well as the lack of transboundary cooperation. Furthermore, the intertidal environment is very complex and variable at multiple scales, which makes it difficult to correctly determine the status of different coastal (water) bodies. Moreover, the intertidal zone contains many critical transition zones (CTZs) (Wall et al. 2001), which add to the complexity. This together with lack of data adds to the problem of which management approaches and responses/actions to follow. Most selection models for marine or terrestrial reserves do not consider the ecological interactions between land and sea (Stoms et al. 2005), even though integrated land and sea conservation planning is essential for success (Álvarez-Romero et al. 2011).

There is no miracle solution to the challenges of habitat degradation (and related problems) and which effective management tools to use, but this study is the first step to highlight the importance of the intertidal zone and to understand what management options that could be tested in adaptive ways (see Table 1). The results show that there are several strategies that could be tested and adapted to the different regional needs. However, it is important to note that many of the experts do not select any of the extremes in the ranking scores (i.e., 1 or 4), but mostly 3, illustrating that they tend to position a "safe" place in the ranking and probably revealing insecurity. In addition, the fact that some strategies, e.g., small enclosures and size limits, were given extreme values among respondents, ranging from none to very high, is interesting. The multivariate analysis of the experts' support for the different management strategies generally showed an even pattern (most answers of experts fall close to each other), but a few outliers were found, with deviant level of support. The results show that outliers were found among both social and natural scientists. Such a situation can be a possibility as well as a constraint. If these experts have great power and are very influential, their specific views can have large impacts. At the same time, diversity and plurality of knowledge and background could be enriching for the planning and envisioning process.

Developing ICZM plans involving local people (participatory approaches and/or co-management) was viewed as the most important management strategy of the intertidal zone, suggesting a broad recognition of the importance of involving users in management. ICZM is recognized as an effective management strategy in the WIO region, but with several challenges (Coughanowr et al. 1995; Gallagher 2010), and we can, for example, still see a lack of specific actions for the intertidal zone. There are few good examples of intertidal management approaches used and tested in the WIO region. In South Africa, ICZM focusing on the intertidal zone and involving local people has been carried out in Coffee Bay on the Wild coast (in the former Transkei area) for rehabilitating mussel (*Perna perna*) beds on overexploited and denuded rocky shores (which works well on within-shore scales taking ca 1 year to recover mussel beds) and managing the recovered mussel beds (Siegfried et al. 1985; Dye and Dyantyi 2002; Calvo-Ugarteburu personal communication). In Tanzania, alternative livelihood projects such as half-pearl farming, shell-craft jewelry making, beekeeping, seaweed farming, fish farming, tourism, and petty businesses have been initiated with varying success (e.g., Torell et al. 2010).

For most management strategies, it is important to understand the basic ecology of the different ecosystems, which is actually often missing in various aspects in the WIO region (from knowledge of species life histories to ecosystems' processes such as connectivity and resilience). Therefore, it is not surprising that conducting research on important species and their relation to intertidal ecosystems was ranked as very important. Further, the research option and the habitat maps and remote sensing received the highest proxy (confidence/importance) of all, indicating the need for baseline data. By-laws and traditional and local ecological knowledge also received very high proxy, probably mirroring the lack of scientific knowledge, but at the same time showing an understanding and valuation of already existing valuable knowledge among the local population. In addition, this reflects awareness about regional diversity and the necessity to tailor management solutions to local conditions. The power of knowledge and understanding for an improved environment was also clearly recognized, and the awareness campaigns and education programs were ranked the third most important strategy and received a high proxy together with laws against trade, showing awareness at both local and global scales. Temporal and/or spatial closures were viewed as a very important strategy; spatial closures are very common, e.g., in forms of no-take zones, and these closures can have benefits such as spillover effects of larvae, although for some species there is no evidence of such spillover effects (Ludford et al. 2012). Closures in the intertidal zone are, however, still very rare in the WIO region.

An important challenging question is if intertidal management is actually needed. Our study shows that the intertidal zone in the WIO is an area lacking much research, monitoring, and management which could be interpreted as an area of low interest and importance. We argue that before we know more about the intertidal zone in the WIO region, it should be treated as an important area, as research on intertidal zones in other parts of the world, suggests that the intertidal zone is of great importance (e.g., Wall et al. 2001; Sloan et al. 2007; Barbier et al. 2011).

Management today is usually divided into land and sea with little focus on the overlapping area. It seems plausible

to create institutions dealing with the intertidal zone for a sustainable future, as there is a need to consider the overlap between land and ocean instead of separating the areas. The way forward for better intertidal management is not an easy one. Given the variety of habitats in the intertidal zone, the consideration of specific plans for many small areas/habitats to be unrealistic; however, a more encompassing organizational unit could be an interesting development.

Conservation and management are expensive and time-consuming, so resource optimization needs to be promoted. The lack of research for several ecosystems in the intertidal zone of the WIO is a problem, even though certain ecosystems, associated species, and important ecological functions might be highly valuable and need protection/management. Furthermore, most management strategies suggested here can be applied to all ecosystems within the intertidal zone. For example, temporal and/or spatial closures could be applied to a variety of habitats such as salt marshes, rocky shores, seagrass meadows, and sandy beaches. Despite the fact that this contribution is mostly focused on the WIO, the general interest in the intertidal zone from the Indo-Pacific is presently increasing and several reviews are emphasizing the importance of the resources of the different habitats, particularly seagrasses (de la Torre-Castro and Rönnbäck 2004; Unsworth and Cullen 2010; Coles et al. 2011; Cullen-Unsworth et al. 2013). It is important to note that this study is the first step in trying to deeply understand the intertidal zone in the WIO; however, we acknowledge the limitations. For example, the study represents only voices from a very specific group out of a diverse group of stakeholders, and in addition, the low number of participants in the workshop is another aspect of limitation. The reason for this is still unclear; it could be because of a generally low interest for the intertidal zone or a low representation of people actually working with the intertidal zone. It could also be that the session took place during the last day of the symposium when people were tired or had already left. For future studies, we recommend catching all voices with particular interest in the local resource users; also, a comparative approach of what other countries or regions are facing could be of interest.

The intertidal zone is an important "bridge" between land and sea, characterized by its diverse and complex interacting environmental, chemical, physical, and biological structure in a condensed area. The zone is in need of creative management solutions to improve sustainability. Our study provides critical useful information by presenting the first overview of the intertidal zone in the WIO along with new ideas on what management strategies to test, the importance of monitoring, and the immediate need for research.

Acknowledgments We are grateful to the experts working in the Western Indian Ocean who responded to the questionnaire and participated in the "workshop". We would like to acknowledge the following people for their valuable inputs to this paper: S. R. Mwaitega, T. M. Daw, J. Okello, N. Kautsky, A. Muthumbi, C. Halling, A. J. Mmochi, H. M. Hajj, O. Henriksson, D. Murage, T. Lavitra, S. Benbow, T. L. Jörgensen, S. Muando, E. Wood, J. Rubens, L. Scott, M. E. Asplund, S. C. Masuka, L. Rasmusson, A. W. Mwandya, H. Eriksson, D. S. Mukaka, U. Kloiber, M. Igulu, A. MacDonald, J. Larsson, C. M. Kihia, A. Knudby, D. J. Msangameno, N. Wambiji, F. Lanshammar, E. Fondo, Y. Tibirçá, P. Scarlet, J. Okondo, T. Andrew, R. Milne, S. Brumme, C. Rogito, and J. Nyamora. Additionally, there are several anonymous experts whom we would like to thank. Further, we would like to acknowledge WIOMSA for the possibility to conduct a workshop/side event at the 7th WIOMSA Scientific Symposium (24–29 October 2012) held in Mombasa, Kenya. L.M.N. acknowledges financial support from the Western Indian Ocean Marine Association (WIOMSA), under Grant No. MASMA/books/04/12, and conference support, as well as the Åbo Academy Jubilee foundation, Finland. M.T.C. acknowledges the financial support from Sida (Swedish International Development Cooperation Agency) and VR (Swedish Research Council) 344-2011-544. M. G. acknowledges the financial support from Sida (Swedish International Development Cooperation Agency).

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