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Patterns of Mangrove Resource Uses within the Transboundary Conservation Area of Kenya and Tanzania

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Abstract: Mangrove forests provide a wide range of goods and services that sustain communities around the world. This paper explores utilization patterns of extractable mangrove resources by communities within the proposed Kenya–Tanzania transboundary conservation area (TBCA). Some 152 household surveys and 12 nominal group technique discussions were carried out. At least 16 direct-use products were reported to be extracted from the mangroves, with 90% of households found to use mangrove products. Changing patterns of mangrove use in the areas and accessibility point towards unsustainable utilization and promote illegal activities. Mangrove use patterns also show a high level of mangrove dependence by communities for their livelihood. Overharvesting of mangrove wood products is reported to be the major threat facing the forests. There is a need to address the problems of open access through capacity building and awareness creation, development and implementation of harvest plans, and introduction of alternative livelihood options. The results of this study can be used to inform development of the proposed TBCA as well as the establishment of a conservation policy in order to contribute to sustainable utilization of mangroves. These findings are important within the TBCA as well as similar environments around the world.

Keywords: mangrove use; transboundary conservation area; sustainability; Kenya

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1. Introduction

Mangrove forests are among the most productive ecosystems on Earth [1]. They are of great importance to society, providing a wide array of goods and services to people, including harvestable wood and non-wood products, coastal protection, biodiversity conservation, and climate regulations [2,3]. However, human influence on mangrove ecosystems is significant and has led to global loss and degradation of these forests at rates of 1–2% per year [4–6]. Though the rate of decline may now be less globally [6–9], loss of mangrove forests is ongoing and higher in certain areas [10,11].

In most governance contexts, the management of mangrove forests is a shared responsibility of different national or subnational agencies [7,12]. This often leads to conflicts due to poor institutional coordination or unclear delineation of competences [13]. Some mangrove forests transcend international boundaries, further complicating their management across the transboundary areas. This is because international borders are political and thus

any shared resources are separated and put under different management regimes. Marine ecosystems including mangroves are often characterized by unsustainable resource use patterns leading to habitat destruction, biodiversity loss, and increased suffering to people depending on them [14–17]. In transboundary areas, this may even be exacerbated because of lack of enforcement and other governance priorities for such border regions [18].

In the transboundary area of Kenya and Tanzania, illegal activities and overexploitation of resources, alterations in freshwater flow, and climate-related hazards are some of the threats mangrove ecosystems are facing [19–21]. For instance, Kenya lost 18% of its mangroves between 1985 and 2010, while Tanzania lost 18% of its mangroves between 1980 and 2005, translating to a loss of 0.7% per year due to these threats [21,22]. Consequently, this has resulted to reduction in fisheries harvest, shortage of firewood and [11,23] building materials, and increased shoreline erosion [12,24]. Poor resource conditions and poverty have thus led to changes in livelihoods of coastal people in the area [25] This is because the quality of people's lives and their survival in the transboundary area of Kenya and Tanzania is heavily dependent on the continued existence and supply of mangrove forest resources. A collaborative management framework is therefore essential to ensure sustainability of natural capital within the transboundary areas. One of the governance approaches would be the establishment of transboundary conservation areas to protect ecosystems and mitigate threats that extend across multiple jurisdictions and boundaries and development of joint management plans across borders that include a wide range of mangrove management stakeholders.

The governments of Kenya and Tanzania have initiated a process for the development of a transboundary conservation area (TBCA) spanning the coastal area from Diani in Kenya to Tanga in Tanzania. The projected TBCA aims at the conservation of land and seascape and the ecosystems for continued provisions of goods and services to people within the area [20]. Prior to the establishment of a TBCA, biophysical baseline data are required to enable the monitoring of changes over time. Some of the baseline data required include status and conditions with regard to natural capital, household data, and utilization patterns of key resources within and adjacent to the TBCA. The current study aimed at providing data and information on harvestable mangrove products within the Kenyan side of the TBCA, utilization patterns, and drivers of change, in order to contribute to their sustainable utilization.

Mangrove Management within and Adjacent to the TBCA

Mangroves in Kenya and Tanzania are gazetted as forest reserves, which restricts their use by communities. There have been significant advances regarding mangrove management at the national level in both Kenya and Tanzania that include development of national mangrove strategies. In Kenya, the development and sustainable management of forest resources, including mangroves, is provided by the Forest Conservation and Management Act (FCMA) of 2016 and its amendments. Communities have the legal mandate to co-manage designated forest areas through registrations of a Community Forest Association (CFA), an approved Participatory Forest Management Plan (PFMP), and the signing of a Forest Management Agreement (FMA) specifying user rights and benefits that accrue to communities. Through the FCMA, communities are allowed access to both consumptive and non-consumptive forest resources and activities such as fuel wood collection, beekeeping, ecotourism, collection of medicinal herbs, and harvesting of timber and other benefits that may from time to time be agreed upon between the CFA and KFS. The Fisheries Act 2016 and the Beach Management Unit (BMU) regulations and their revisions authorize collaborative management of fisheries resources and provide for the protection of fish breeding areas, including mangroves [26].

The Kenya Forest Service (KFS) is the national institution vested with responsibilities of managing all forests in the country, including mangroves. The KFS issues licenses and monitors harvest operations. To remove a headload of firewood, community members pay the KFS KSh100 (≈0.66 USD) per month. A license to remove building poles costs about

100 USD per annum. With this permit, a licensee is granted a quota to harvest mangroves within a designated area for one year [27]. Depending on the resource base, the KFS can grant more than one licensee to operate in the same forest block. Licensees will then hire local cutters to remove the forest products. Cutters inform the licensee about the number of poles harvested and the licensee in turns informs the KFS. The numbers cut are counted, the fee paid and the poles are hammer-marked (ibid., p. 260), making them ready for the market. In 2018, however, the cabinet secretary in charge of environment and forests in Kenya imposed a ban on further mangrove harvesting with the objective of increasing the country's forest cover and curbing illegal logging of mangrove trees. In 2019, this ban was partially lifted in Lamu County, where mangrove harvesting is a major livelihood activity.

In mainland Tanzania, the Forest Act (2002) provides for the participatory management of forests, including mangroves. Mangrove collaborative management plans (MCMPs) are developed to guide the use and conservation of mangrove ecosystems. Village environmental management committees (VEMCs) are established to implement the MCMPs. Despite forest users having exclusive rights to the products, the forests remain the property of the central government [17]. Harvesting mangroves for commercial purposes requires a harvesting permit from the district forestry officer (DFO). Communities living adjacent to forests are required to apply for a harvesting license for subsistence use. Priority is given to applicants with modern harvesting technologies. The area to be harvested should be indicated in the district harvesting plan, and issuing the harvesting license will be based on the experience of the applicant. The applicant will then be requested to report to the villages adjacent to the forest that will be harvested and present his/her license. Unlike in Kenya, where it is the licensee who informs the KFS of the number of poles they have harvested, in Tanzania, the village council together with the DFO supervise the harvesting to make sure that the allowed species and numbers of trees are harvested, as indicated in the license [28,29].

Despite the existence of a legal framework for mangroves and the recognition of community rights in Kenya and Tanzania, there have been additional institutional challenges in mangrove management. For instance, in Tanzania, inadequate coordination between forestry and marine conservation agencies has resulted in ineffective mangrove management [30]. Poor interaction with local communities has also been highlighted as a drawback for their efficient conservation [31]. Governance and institutional issues that have intensified mangrove degradation in Kenya mainly include uncoordinated sectoral approaches to management due to overlapping or conflicting mandates, weak enforcement of existing legislation, and inadequate institutional capacities [19].

2. Materials and Methods

2.1. Descriptions of the Study Area

The projected Kenya–Tanzania transboundary conservation area spans the coast from Diani in Kenya (39°0′0″ E, 4°25′0″ S) to Tanga in Tanzania (39°40′0″ E, 5°10′0″ S), a stretch of approximately 200 km (Figure 1). The TBCA is endowed with numerous coastal and marine resources that play a significant role in local economies and national development. One of the significant ecosystems within the TBCA is mangrove forests [20].

These forests provide harvestable goods and services to people, such as building poles, firewood, fodder, fish, and honey, but there are also non-consumptive uses. Mangroves provide habitats for fish and other wildlife, protect shorelines from erosion, and contribute to offshore productivity [19]. All the nine mangrove species described in the region occur within the TBCA. The dominant species are *Rhizophora mucronata* (Swahili: Mkoko) and *Ceriops tagal* (Mkandaa), occupying more than 70% of forest formation. Other mangrove species in the area include *Avicennia marina* (Mchu), *Sonneratia alba* (Mlilana), *Brugueira gymnorrhiza* (Muia), *Xylocarpus moluccensis* (Mkomafi dume), *Xylocarpus granatum* (Mkomafi), *Heritiera littoralis* (Msikundazi), and *Lumnitzera racemosa* (Kikandaa) [21]. Other plant species associated with mangrove trees also occur, but are quantitatively marginal.

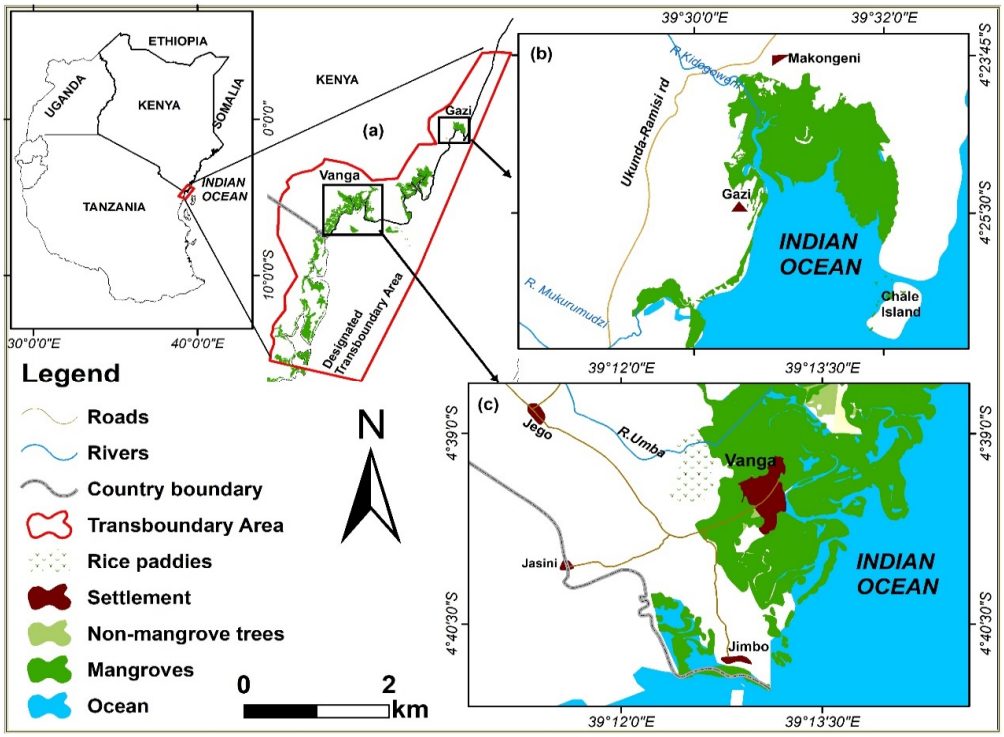

Figure 1. (**a**) Projected TBCA map showing the study sites: (**a**) the TBCA (Kenya), (**b**) Gazi Bay, (**c**) Vanga area (map credit: Fredrick Mungai Mburu).

In terms of socioeconomic characteristics, the TBCA has a rapidly growing human population, with nearly 60% of the rural communities dependent on marine and coastal resources for their livelihoods [20]. These communities share many aspects of culture, religion, and livelihoods and also have cross-border family ties, despite being separated by political boundaries (ibid., p. 52). Fishing is the main economic activity of communities in the area, providing food and contributing to livelihood support. While fishing is predominantly a male activity, women engage in fish-related activities such as fish mongering. The current study concerned mangrove utilization within Kenya's side of the TBCA.

Respondents were selected from Gazi Bay and the Vanga area (Vanga, Jimbo, Jasini villages). Gazi Bay area has a population of approximately 6000 inhabitants distributed over Gazi and Makongeni villages. The total area of mangroves in Gazi Bay is estimated at 715 ha [19]. The Vanga area has a permanent human population of approximately 7900 people and a mangrove area of 4428 ha [32,33].

2.2. Methods

The study used purposive sampling, a non-probability sampling technique, to identify five villages that formed the study sites. Three villages in the Vanga area and two villages in the Gazi Bay area that are the closest and farthest villages from the Kenya–Tanzania border were selected. Systematic random sampling was then used to generate samples for the household surveys. This probability sampling technique was applied in each stratum to select subjects, giving them equal opportunity of being sampled. The systematic technique was applied such that every 10th household was selected for the interviews. Sampling was maintained at 10–15% of total households, as recommended by Mugenda and Mugenda [34]. Overall, some 152 household surveys (Table 1) and 12 nominal group technique applications (Supplementary Materials) were received. Purposive sampling was used to identify participants for the nominal group discussions. The nominal groups were made up of forest user groups who carried out activities in the mangrove areas within the study sites. The study took place in April 2019 (Table 2).

Table 1. Sample frame for the household interviews.

Site	Village	Number of Households	Sampled Households
Vanga area	Vanga	680	68
	Jimbo	80	8
	Jasini	35–40	6
Gazi Bay	Gazi	400	40
	Makongeni	300	30
	Total	1500	152

Table 2. Characteristics of the nominal groups formed to generate data on goods from mangrove goods and threats to the system.

Village	Workshop Group	No. of Participants	Age < 50	Age > 50	Min and Max Age	Median
Vanga	Firewood sellers	9	6	3	31 and 60	47
Vanga	Vanga dagaa sellers	9	8	1	26 and 50	40
Vanga	Vanga fishermen	7	3	4	41 and 66	38
Vanga	Vanga conservation group	10	9	1	37 and 52	51
Jimbo	Jimbo firewood sellers	9	8	1	20 and 62	47
Jimbo	Jimbo *dagaa* sellers	10	7	3	32 and 59	46
Jimbo	Jimbo environmental group	8	5	3	23 and 70	42
Jasini	Jasini *dagaa* sellers	7	5	2	25 and 70	29
Gazi	Gazi ecotourism boardwalk	5	1	4	35 and 64	43
Gazi	Gazi fishermen	7	6	1	18 and 56	36
MakongeniBaraka conservation group		7	6	1	38 and 70	35
MakongeniMakongeni fishermen		5	5	0	28 and 40	55

Dagaa—sardines.

The nominal group technique, a structured approach to a focus group discussion, followed the process described by Hugé and Mukherjee (2018) [35]. The nominal group technique is an interactive group decision-making technique primarily to elicit judgment from stakeholders. It involves several steps where participants are first requested to provide information individually (hence nominal) to questions asked by a moderator and then all ideas generated are listed. Participants are then invited to seek clarification or further elaboration on any of the ideas proposed by the other participants. The moderator collates all information, creates a list of unique items and then asks participants to select and rank the ideas from the list generated. The most highly rated ideas are then the most favored actions (ibid., p. 35).

The data collected were consolidated, coded, and analyzed using descriptive and inferential statistics. Chi-squared tests (χ^2) were used to determine whether there was any significant difference ($p < 0.05$) in mangrove use patterns between the Vanga area and Gazi Bay, as well as among the five villages. Ranking of mangrove goods and threats facing them was used to gauge the perceived levels of importance of these goods and the severity of the threats. Data analysis and graphical presentation of the results were performed using both Statistical Package for Social Sciences (SPSS) version 23 and Microsoft Excel platforms.

Ethics clearance for the study was granted by the Pwani University Ethical Review Committee, and the National Commission for Science, Technology, and Innovation issued the research permit. Further, research clearance was obtained from the local administration in the study sites to conduct the study.

3. Results

3.1. Use of Mangrove Forest Products

At least 90% of respondents indicated using mangrove goods directly (Figure 2). There was no significant difference in respondents' use of mangrove goods among the study sites (χ^2 = 5.284, d.f = 8, p = 0.259).

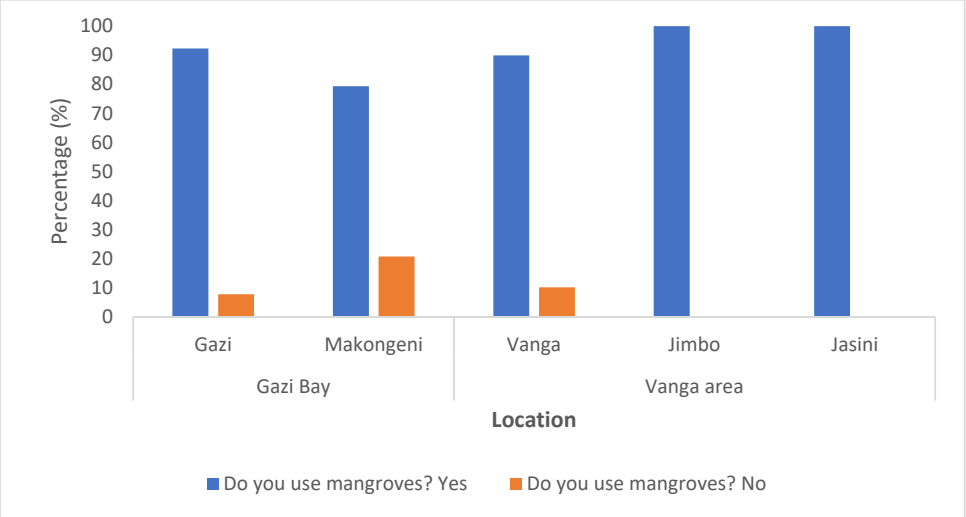

Figure 2. Percentage of responses in relation to direct use of mangrove resources in Gazi Bay and Vanga area.

A total of 16 different products were reported to be extracted from mangrove forests in the study area. The most valuable mangrove product reported was firewood, followed by fisheries resources, building poles, honey, and traditional medicine (Table 3).

Table 3. Nominal group technique results showing resources extracted from the mangrove forest ranked in order of importance.

Goods Extracted from the Mangrove Forest	Total Number of Votes	Overall Score	Number of Groups Mentioned in	Rank
Bait	18	39	7	-
Building poles	56	198	12	3
Buoy	4	8	1	-
Charcoal	11	26	5	-
Facial cosmetics	3	6	2	-
Firewood	76	305	12	1
Fish	66	230	12	2
Fish fingerlings	15	73	1	-
Fodder	5	14	1	--
Honey	65	159	12	4
Mangrove tannin	3	4	3	-
Mataruma (timber for boat making)	26	51	8	-
Medicine	33	77	9	5
Poles for bed leggings	3	11	2	-
Pondo (paddles/oars)	18	49	5	--

Votes received: 1 is most important = 5 points; 5 is least = 1 point; score is a sum of rating of each idea; rank refers to the position of an item within a group.

Non-wood resources extracted from the mangrove forests include honey, shellfish, bait, and traditional medicines. To reduce overdependence on mangrove wood for building and energy, communities within the TBCA (Kenya) have resorted to using alternative products

such as coconut husks and charcoal and timber sourced from terrestrial forests. There was a significant difference in the alternative sources of wood products across the sites (χ^2 = 16.9, d.f. = 8, p = 0.031) Some of these products such as charcoal are bought, while others such as coconut husks are collected for free. One has to get a permit from the Kenya Forest Service in order to obtain wood from the terrestrial forest. Communities in the Gazi area (Gazi and Makongeni villages) have established woodlots of fast-growing terrestrial tree species to meet some of their wood requirements. They are also located near the Gogoni terrestrial forest, from where they can get alternative firewood. However, communities in the Vanga area are geographically isolated and surrounded mostly by mangrove forests. Because villagers were not in a good position to be selective, they would harvest or use what was most readily available to them, which was either coconut husks or firewood gathered from surrounding bushes.

3.2. Patterns of Mangrove Resource Use in the TBCA (Kenya)

Of all mangrove products, fisheries products are the most important resource extracted daily from the forest, at 48% of reported use frequency (Table 4), Other products collected daily included firewood (6.8%) and food such as wild honey (0.7%).

Table 4. Percentage of responses in relation to frequency of use of mangrove products in the TBCA (Kenya).

Frequency of Use	Firewood	Timber	Food	Medicine	Wild Fish	Farm Fish	Other Products
Daily	10 (6.8%)	0 (0%)	1 (0.7%)	0 (0%)	71 (48%)	0 (0%)	0 (0%)
Weekly	32 (21.6%)	0 (0%)	0 (0%)	0 (0%)	4 (2.70%)	0 (0%)	3 (2.0%)
Fortnight	7 (4.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Monthly	9 (6.08%)	0 (0%)	1 (0.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Other	25 (16.9%)	60 (40.5%)	5 (3.4%)	2 (1.4%)	9 (6.1%)	1 (0.7%)	4 (2.7%)
Don't use	65 (43.9%)	88 (59.5%)	141 (95.3%)	146 (98.6%)	64 (43.2%)	147 (99.3%)	141 (95.3%)

On a weekly basis, the most extracted product was firewood (32%). Other weekly harvested products included wild fish (2.7%) and other products (2%), such as bait for fish and mollusks collected from the mangrove areas. Forest products such as medicine and repair timber for houses and boats were extracted as their needs arose. In Jimbo village (Vanga area) and Gazi village (Gazi Bay area), the collected firewood was mainly used for boiling of sardine fish (or *dagaa*). A total of 125 and 20 registered *dagaa* dealers were reported in Jimbo and Gazi villages, respectively. The frequency of use of firewood by the *dagaa* dealers depended on the quantity of fish they boiled per day (Table 5). On average, *dagaa* sellers boil two to four baskets of sardines per day.

Table 5. Firewood quantity used to boil sardines and frequency of use in the TBCA (Kenya).

Firewood Quantity	Quantity (No. of Baskets/Day) *	Periodicity (Days)
Load (*mzigo*)	1	1
Size carried by a motorbike	2	5
Cart (*mkokoteni*)	2	10
	10	2–3
Small dhow (*shehena ndogo*)	2	10
	10	2–3

Table 5. *Cont.*

Firewood Quantity	Quantity (No. of Baskets/Day) *	Periodicity (Days)
Medium-sized dhow (*shehena ya kati*)	2	14
	10	5–7
Big dhow (*shehena kubwa*)	2	16
	10	7–10

* 1 basket size (*tenga*) = 60–65 kg wet weight or 18–20 kg dry weight.

Firewood sold to the *dagaa* sellers was measured in different quantities, ranging from a load to large quantities that could fill carts and dhows. A load of firewood could last for a day, as it could only be used to boil a basket of *dagaa.* However, large quantities of firewood could last for more than two days depending on the quantities of *dagaa* they could be used to boil in a day.

3.2.1. Harvesting Locations

On the question of where mangrove products were extracted, at least 50% of the respondents indicated that the products were sourced deep in the forest. Some 23% of the respondents were not aware how the mangrove products were extracted as they did not use the products or because they were not the ones who did the actual harvesting. About 15% of the respondents reported collecting firewood along the forest edge, 5% collected randomly, whereas 4% reported fetching firewood from deep in the forest (Figure 3). There was a significant difference between areas where mangrove products were harvested across the study sites ($\chi^2 = 62.219$, d.f = 20, $p < 0.001$). All the respondents who harvested mangroves from far-off areas were from the Vanga area (Vanga and Jimbo villages). Over three fifths (66.7%) of these respondents were from Jimbo, while 33.3% were from Vanga. They reported crossing into the Tanzanian side and extracting firewood from Kigomeni, Mbayai and Kendwa sites.

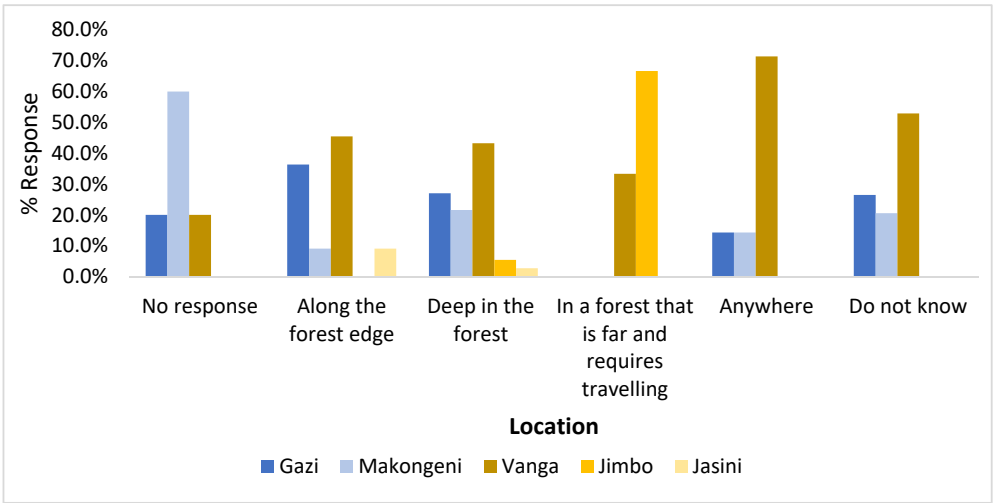

Figure 3. Percentage of responses in relation to mangrove harvesting locations within the TBCA (Kenya-origin respondents).

3.2.2. Mangrove Harvest Permits

The respondents indicated applying for licenses to harvest mangrove wood products from the KFS. However, the harvesting systems were different in the Gazi and Vanga areas. While Gazi communities purchased mangrove poles directly from a licensed harvester at a fixed price, in Vanga, wood was purchased from different mangrove cutters at various prices (Table 6). The mangrove poles were sold in scores—20 poles. *Nguzo*-sized poles

fetched the highest prices in the market, despite their low demand. This was followed by *vigingi*, *boriti*, *mazio* and *pau*.

Table 6. Prices of mangrove poles to communities in different study sites before and after the mangrove ban.

Utilization Class	Diameter Range (cm)	Quantity	Gazi Bay		Vanga Bay	
			Price before Mangrove Ban (KSh)	Current Price (KSh)	Price before Mangrove Ban (KSh)	Current Price (KSh)
Fito	2.5–3.9	score *	200	Ban ongoing	120–150	200–600
Pau	4.0–7.9	score	300	Ban ongoing	400	600–800
Mazio	8.0–11.4	score	1000	Ban ongoing	400	600–800
Boriti	11.5–13.9	score	3000	Ban ongoing	400–500	1000–2500
Nguzo	14.0–20.5	pole	Not sold	Ban ongoing	150–200	300–500
Vigingi	20.5–35.0	pole	150	Ban ongoing	100	1400–2000

* 20 poles = 1 score (*korija*); 1 USD = 128 Ksh as of 4 March 2023.

Firewood in the Vanga area (Vanga, Jimbo and Jasini) is sold by firewood harvesters at different prices depending on the quantity required (Table 7). These cutters have continued with their activities despite the ban on harvesting mangrove products which is illegal.

Table 7. Firewood prices by firewood sellers in Vanga Bay (amount in Ksh) before and after the mangrove ban.

Firewood Quantity	No. of Pieces	Before the Ban	Current Prices (Ksh)
Piece (*kipande*)	1 (2–5 cm) diameter)	5–7	10
Bunch (*fungu*)	5–10	30–50	60–70
Load (*mzigo*)	10–20	150–200	200–300
Cart size full (*mkokoteni*)	Varies with size	800–1000	1000–1200
Small-sized dhow (*shehena ndogo*)	Varies with size	500–600	800
Medium-sized dhow (*shehena ya kati*)	Varies with size	1000	1500
Big-sized dhow (*shehena kubwa*)	Varies with size	1500	3000
Size carried by a bicycle	Varies with size	500	700
Size carried by a motorbike	Varies with size	700	700–1000

1 USD = 128 Ksh as of 4 March 2023.

There was no significant difference in the access level of mangrove products among the study sites (χ^2 = 15.935, d.f = 8, p = 0.048). When respondents were asked whether it has become easier or more difficult to harvest mangroves, 74% indicated that it has become more challenging due to access restrictions and shortages. The respondents attributed the difficulty to the presence of forest laws and the nationwide ban on harvesting of mangrove wood, which was their main and/or only product of use. Consequently, this has continued to negatively impact the people who lack alternative sources of wood for building and energy. However, of the sample, 24% were not aware whether it is now easier or difficult to harvest mangrove. This was because they attested to no longer using mangrove products and more so they indicated that they were not engaged in mangrove conservation activities. Only 2% indicated that harvesting the products had become easier.

3.2.3. Mangrove Species Preference

Communities within the TBCA could correctly identify different mangrove species in their areas, their local names, and the parts of the tree that are used (Table 8). Even though different mangrove products were extracted from different parts of the mangroves, there was similarity in how mangroves were used among the study sites. The uses of the products were both consumptive and non-consumptive. Some local mangrove names differed due to different Swahili dialects within the study sites.

Table 8. Mangrove species, their local names, and parts used (responses from TBCA, Kenya).

Species	Local Names (Swahili)	Part Used	Uses
Avicennia marina	Mchu; mchwi	Trunk/stem	Consumptive use: Provides nectar for honey; making mortar and pestle; firewood; traditional bed (*mwakisu*)
		Leaves	Consumptive use: Insect parasite treatment of chicken; traditional medicine (treating reported demon possession); mosquito repellent; fodder Non-consumptive use: Season/weather indicator (when leaves fall it indicates the beginning of the rainy season)
		Branches	Consumptive use: Firewood
		Roots	Consumptive use: Medicine
Brugueira gymnorrhiza	Muia; mrungu; mkifi; ndovu	Branches/Stem	Consumptive use: Construction poles (*fito*)
Ceriops tagal	Mkandaa	Leaves	Consumptive use: Treating reported demon possession
		Branches	Consumptive use: Firewood
		Stem	Consumptive use: Construction poles (*pau*, *mazio*, *fito*, *nguzo*); dye for mats; natural colorant for cosmetic; *pondo*; boat making/repair; fish traps (*uzio*, *malema*); firewood
Heritiera littoralis	Msikundazi; mtakawa	Branches/stem	Consumptive use: Rope used in making *wando* (a fence used as a fishing trap)
Lumnitzera racemosa	Kikandaa; mnyanywa	Branches/stem	Consumptive use: Firewood
Rhizophora mucronata	Mkoko; msisi; Mraaza; mdiago	Branches	Consumptive use: Firewood
		Stem	Consumptive use: Construction poles (*mazio*, *pau*, *boriti*); boat making, dye; mosquito repellent
Sonneratia alba	Mpia; mlilana	Seed	Consumptive use: Playing item for kids Non consumptive use: Season/weather indicator (fruits help tell beginning of rainy season)
		Flower	Consumptive use: Contains nectar to stimulate saliva in children for proper food lubrication and digestion
		Branches	Consumptive use: Firewood
		Stem	Consumptive use: Wood for boat making (*mataruma*); firewood construction poles (*boriti*)
Xylocarpus granatum	Mronga; mkomafi	Fruit/seed	Consumptive use: Medicine (treatment of jiggers, cramps, stomachache), facial cosmetics
		Stem	Consumptive use: Boat making, bed legging (*matendegu*); construction poles (*pau*, *vigingi*, *boriti*)
Xylocarpus moluccensis	Mkomafi dume	Branches/stem	Consumptive use: Firewood
Mangrove areas			Consumptive use: Worm bait, prawns, crabs; oysters; wild fish Non-consumptive use: Fish farming area for milkfish and mullets

Across all study sites, the preferred mangrove tree species are *Rhizophora mucronata* (Mkoko), *Ceriops tagal* (Mkandaa) and *Sonneratia alba* (Mlilana) for wood. Mangrove trees are harvested by the local communities for building poles, firewood, furniture, and boat ribs. At Gazi Bay, *Rhizophora mucronata* is the most exploited mangrove species, whereas in Vanga, *Ceriops tagal* is mostly preferred (Figure 4). Communities also collect honey, traditional medicine, shellfish, and fish bait from mangrove areas.

3.2.4. Perceived Condition of Mangroves in the TBCA (Kenya)

Fifty-two percent (52%) of the respondents gave their views on the availability of construction poles over the past 5 years. Thirty-seven percent (37%) of them felt that availability of construction poles had decreased, 7% indicated that availability had stayed the same, while 7% felt that the availability had slightly increased. From the 65% of the respondents who gave their views on the availability of firewood, 45% felt that the availability had decreased, 10% indicated that availability was the same, while 11% felt that firewood availability had increased. Decline in both construction poles and firewood was reported more in the Vanga area than Gazi Bay (Figure 5).

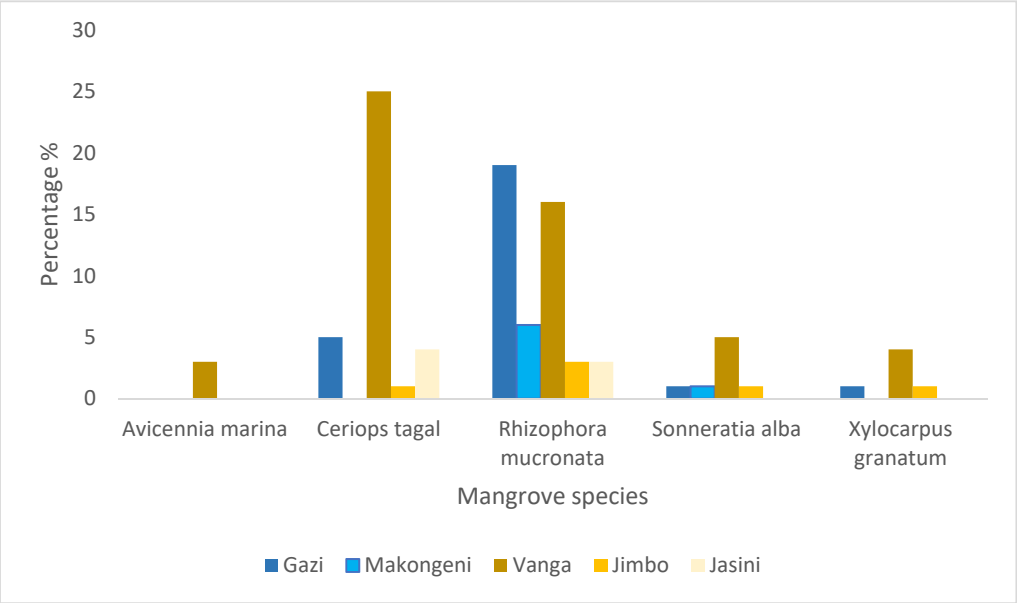

Figure 4. Percentage of responses in relation to the most utilized mangrove species for wood products in the TBCA (Kenya).

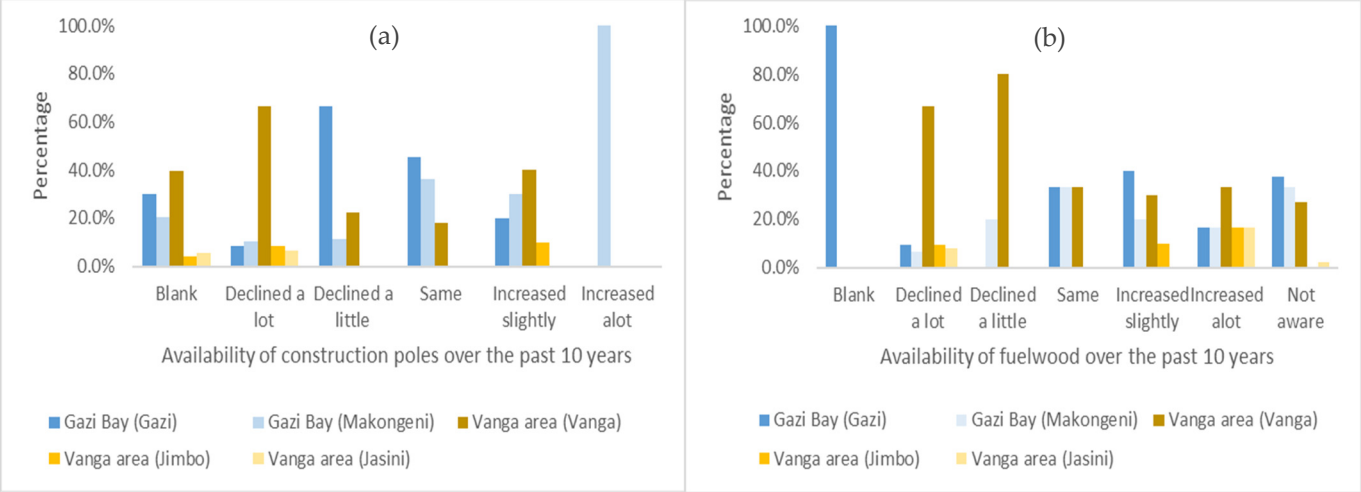

Figure 5. Percentage of response in relation to availability of (**a**) firewood (**b**) construction poles over the past 10 years in the TBCA (Kenya).

3.3. Threats to Mangroves within TBCA as Reported by Respondents

Across all the sites, major threats facing mangroves within and adjacent to the TBCA were reported as overexploitation of wood products, shoreline change, and sedimentation. Other threats were identified as pollution, storm charges, insect infestation and climate change. Despite being mentioned in one workshop only, lack of security was indicated as a threat by three respondents. Threats that were mentioned in only one workshop were eliminated. This includes seedling trampling, use of power saws, freshwater obstruction, infrastructure development, clearing of mangroves for shrines, population increase, corruption and fire outbreak (Table 9).

Table 9. Nominal group technique results showing reported threats to mangroves within the TBCA (Kenya).

Threat to Mangroves	Total Number of Votes	Overall Score	Number of Groups Mentioned	Rank
Charcoal burning	12	34	3	
Climate change	7	20	2	
Dry and hot conditions	13	36	3	
Floods	51	173	9	2
Illegal fishing methods	11	37	3	
Illegal harvesting	51	172	10	3
Insects	9	22	2	
Lightning	18	46	4	
Overharvesting	72	261	12	1
Pollution	39	91	7	5
Sedimentation	22	51	5	
Soil erosion	39	111	6	4
Strong winds	24	77	5	

Votes received: 1 is most important = 5 points; 5 is least = 1 point. Score is a sum of rating of each idea. Rank refers to the position of an item within a group.

4. Discussion

4.1. Use of Mangrove Forest Products

Various mangrove tree species are used for different purposes worldwide [13]. Within the Kenya–Tanzania transboundary area, mangrove forests provide harvestable wood and non-wood products such as building poles, and firewood, honey, traditional medicine, mangrove tannin, and fisheries resources. This is in addition to the habitat and protective functions provided by the forested ecosystem. Our results (for the projected transboundary conservation area on the Kenyan side) are consistent with previous observations in Kenya [36] and other parts of the world, such as Bangladesh, Benin, Brazil, India, the Philippines, and Thailand, where mangroves were shown to provide multiple goods and services to society [13,37,38].

The major use of mangroves on the Kenyan side of the TBCA is in building and firewood. In Kenya, it is estimated that 70% of the wood requirement by the coastal communities is met by mangrove forests [19]. Differences between villages in mangrove areas were observed, but were limited. Mangrove wood is generally preferred for fuel because it is dense and of high heat capacity compared to other tree species [13,39,40]. However, in southwest Madagascar, communities prefer firewood obtained from dry forests for being drier and more easily combustible than local mangrove wood [40]. Generalization is thus not possible regarding the role of mangrove wood due to difference in preferences in different areas worldwide, which makes local reports relevant. Several mangrove species are also resistant to termites, and as such, preferred for building and constructions [19,39,40]. Different size classes of mangrove poles are used for construction within the TBCA. *Rhizophora mucronata* is the preferred mangrove species for building because it grows tall, straight, and is resistant to termite attack [21]. On the other hand, *Ceriops tagal* is mainly used due to its high availability. Other species, like *Sonneratia alba* and *Xylocarpus granatum*, are used for boat building and furniture because they attain large sizes, and the wood is easy to adapt or fits to the required curve.

Gok 2017 [19] indicates that more than 85% of fishing activities along the coast are carried out by artisanal fishermen in the shallow inshore areas within and adjacent to the mangroves, which directly employ more than 20,000 fishermen. This was observed in the study site, where fish is among the most important and frequently extracted resource from the forest with shrimp fry, prawn and crab collection providing food and contributing to household livelihood support. Non-wood products such as medicine were reported to come from *Xylocarpus granatum* seeds, which are valued for their curative properties for jiggers, cramps and stomachache, and body aches. This medicinal value has a positive

impact on the local population's health. *Avicennia marina* leaves and those of *Ceriops tagal*, on the other hand, are reported to remove demons from a possessed person. These leaves are also used as insecticides, i.e., in mosquito repellent, as well as to remove parasites from chickens. Mangrove tannin, which is used for decorating mats and a colorant used by women for beauty purposes, is extracted from the bark of *Rhizophora mucronata* and *Ceriops tagal*. Fruiting of *Sonneratia alba* is reported to signify the current season, while falling *Avicennia Marina* leaves marks the beginning of dry season.

4.2. Mangrove Use and Conservation

There is a high frequency of harvesting mangrove wood products within the TBCA (here reported for Kenya). Mangrove use patterns in the areas and accessibility, however, point towards unsustainable utilization and illegal activities and thus unreported to the KFS (Figure 6). This was mainly observed in Vanga, where there is a tendency of managing mangroves as an open pool system. These findings are contrary to the reported trends in mangrove wood utilization in the area that indicate minimal harvesting (Figure 7).

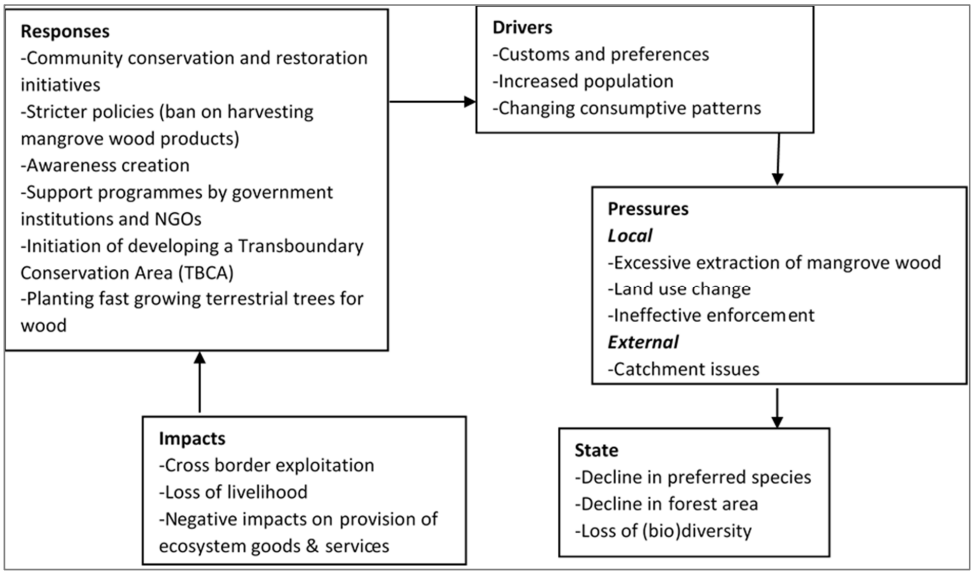

Figure 6. DPSIR (drivers, pressures, state, impact and responses)-type scheme for TBCA (Kenya). DPSIR is a causal framework used to describe interactions between society and the environment.

Selective harvesting of mangroves (whether legal or illegal) is a common practice amongst communities within and adjacent to the TBCA. The findings are consistent with other studies elsewhere, wherein *boriti*-sized poles (butt diameter 8–13 cm) are preferred for construction, with *R. mucronata* being the main targeted species [36]. This is followed by *mazio* (7–9 cm) and *pau* (5–7 cm) utilization classes used for construction. This is consistent with results elsewhere in Kenya, e.g., in Lamu [41] and Mida [36], where selective removal of desired species and pole sizes has led to forest degradation or floristic shifts.

Harvesting of mangrove wood products within the TBCA may be viewed as mainly on a small scale, which is often perceived to have limited ecological impact [42]. However, studies elsewhere have revealed that if not controlled, small-scale harvesting practices result in cumulative effects leading to structural changes and species dominance shifts in the mangrove forest [40,43–46].

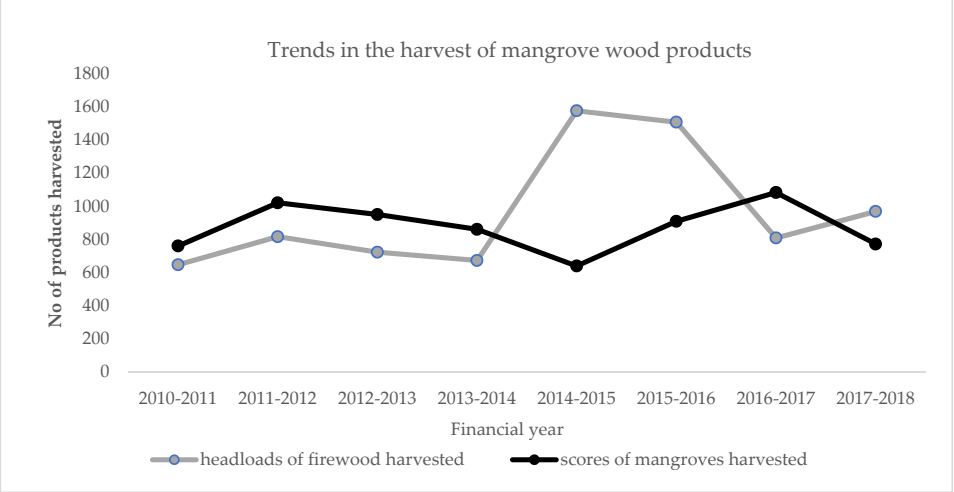

Figure 7. Trends in numbers of mangrove poles (scores) and firewood (headloads) harvested within the TBCA (Kenya) between 2010 and 2018. Data source: KFS records.

Local people also intentionally forage for deadwood from the forest for fuel. They collect dry mangrove branches and stems on a weekly basis, with consumption dramatically increasing during weddings and other celebrations, when households (including those that use alternative fuel) use mangrove wood for cooking. Demand for firewood for commercial purposes was also observed to be on the rise due to increased numbers of *dagaa* dealers who use firewood to boil sardines in the study sites. Foraging for deadwood can reduce levels of naturally occurring deadwood. Wang'ondu (2020) [47] observed that continued cutting of these preferred species before maturity, primarily for house construction, affects the stand structure of mangroves forests near human habitation. This was observed in the study sites, where preference for certain mangrove species and a decline in products such as firewood and poles over the years have made community members in the study area go deeper into the forest in search for them. Decline in both construction poles and firewood was reported more in the Vanga area than Gazi Bay, which is consistent with similar studies carried out in the area [32], which showed Vanga to be a hotspot for mangrove loss and degradation. *Mazio* and *boriti*-sized poles (8–14 cm) have also been reported to be limited in the area due to illegal harvesting that is rampant and noticeable [19].

A temporary ban on mangrove logging imposed in 2018 has resulted in unsustainable practices and negative effects on community livelihoods due to a lack of (known) alternatives, For instance, in Vanga Bay, firewood collectors use boats to cross the border and access firewood from mangroves on the Tanzanian side from islands that are not occupied by people Apart from being illegal, these practices pose a management challenge to mangrove management in Tanzania.

There are, however, conservation efforts in the study sites that are supporting restoration and protection of mangrove forests within the TBCA, for example, Mikoko Pamoja, an initiative by Gazi communities that seeks to conserve and restore mangroves for community livelihood and environmental sustainability. Mikoko Pamoja is globally the first community-type project to protect and restore mangroves through the sale of carbon credits on the voluntary carbon market. Revenue generated from sales of carbon credits is used to support local development projects in water and sanitation, education, health and environmental management [48]. The project has been replicated in Vanga Bay as the Vanga Blue Forest Project, also within the TBCA [32]. These carbon projects are mitigating impacts of climate change, earning income for the local communities and also contributing to conservation of mangrove ecosystems.

4.3. Threats to Mangroves within TBCA as Reported

Like other areas in Kenya, mangroves within TBCA are threatened by a combination of human and natural factors. Major threats facing mangroves are overharvesting of wood products for building and fuel. Poverty, population increase, economic pressure, poor governance, and lack of alternative livelihoods are identified as root causes of loss and degradation of mangroves in the area. Poor governance and law enforcement manifest in mangrove land encroachment, dumping of solid waste, and illegal mangrove harvesting activities. Cumulatively, these activities have led to the reported decline in mangrove forest cover and/or quality within the TBCA [21].

Climate change increases threats such as drought, flooding, soil erosion, and sedimentation, which have negative impacts on mangroves in the study sites. The 1997–1998 El Niño rains that hit most parts of the country resulted in heavy sedimentation and prolonged water stagnation that led to widespread mangrove dieback in Gazi Bay among other mangrove sites along the Kenya coast [19]. This process also caused shifts in species dominance. Sedimentation in the study sites is attributed to upstream activities such as damming of the river supplying sediments and freshwater downstream. Damming of the river Mkurumudzi, for instance, has affected sediment balance of the estuary in Gazi Bay, leading to death of mangroves (ibid., p. 31). Predicted sea-level rise associated with climate change [49] is expected to accelerate loss and degradation of mangroves within TBCA. For instance, accelerated sea-level rise is projected to marginally outpace the net mangrove surface elevation in Vanga which would have a negative impact on mangroves in the Vanga area [50]. Other threats, such as oil spills and plant parasites/woodborers, have been documented in the area [19]; however, they were not mentioned in the workshop, most probably because they go unnoticed.

The numerous products and services derived from mangrove forests and the frequency of their extraction are a clear indication of their importance to the communities within the TBCA (here reported for Kenya). Lack of access, therefore, results in increased illegal activities and degradation of the forest, jeopardizing future provision of products and services.

5. Conclusions

The numerous products derived from the mangrove forests, services provided by these ecosystems, and the frequency of their extraction together are a clear indication of their importance to the communities within the Kenya–Tanzania TBCA. These products are vital for subsistence use and in sources of daily nutrition for the local communities. The products are also preferred because they are perceived to be more affordable and available compared to other alternatives, since they are often obtained free from the mangroves.

Mangroves within Kenya's side of the TBCA are characterized by mixed management systems. The forest within Gazi Bay enjoys a semi-access status following enhanced community-based mangrove management. Here, the sale of mangrove carbon-offset credits on the voluntary market spearheaded through Mikoko Pamoja has enabled communities to gain from conservation and restoration efforts. This is not the case in Vanga, where open-access practices are the norm without community surveillance. Individuals enter the forest and extract construction poles and firewood illegally. With the expansion of Mikoko Pamoja activities in Vanga, this approach is beginning to change for improved mangrove management in the area.

The TBCA (Kenyan part) is characterized by both sustainable and unsustainable resource use patterns. Unsustainable patterns are a result of lack of access to the resource due to restrictions, personal preferences, and lack of alternatives, as well as cultural influences and practices. On the other hand, awareness raising, capacity building, provision of alternative source of wood products, and policies regulating resource use, and enforcement of regulations have contributed to sustainable resource use patterns. Similarly to other sites in Kenya, there is a preference for certain mangrove species and utilization classes within the

TBCA. Of the mangrove species, *Rhizophora mucronata* and *Ceriops tagal* are the preferred species for building and construction.

Mangroves in the TBCA are majorly threatened by illegal extraction of wood products. There is a need for management interventions to regulate the removal of mangrove wood products for their sustainability. Development and implementation of mangrove harvesting plans will assist in guiding mangrove exploitation, while planting of fast-growing terrestrial trees in community lands would provide alternative sources of wood products. There is a need to address the problems of open access through capacity building, education and awareness raising, as well as introduction of alternative livelihood options and acceptable and affordable goods for mangrove products to the communities in the area.

To further prepare for the projected TBCA, a similar research program must be initiated on the Tanzanian side of the TBCA, particularly because management entailing access to consumptive resource use must be coordinated between both countries within the TBCA to overcome non-sustainable practices. The development of the TBCA offers a prime opportunity to better manage and protect shared mangrove resources without jeopardizing the livelihood, culture, or well-being of communities depending on them, but it demands research, continued monitoring, and better (international) institutional coordination. This study can be used by governments in other similar regions to understand challenges and look for ways to collaborate in governing transboundary resources in order to be successful in implementation of a conservation agenda in the affected areas.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16114623/s1, Household Questionnaire.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by Ethical Review Committee (ERC) of Pwani University (reference ERC/MA/010/2019): date of approval 9 October 2020.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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