Original Article

Influence of Covid-19 restrictions on the status of mangrove vegetation in coastal Kenya

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Western Indian Ocean JOURNAL OF Marine Science

Open access

Citation:
Dzoga M, Munga C, Azmiya F, Tole K, Kombwe C, Shee A (2024) Influence of Covid-19 restrictions on the status of mangrove vegetation in coastal Kenya. Western Indian Ocean Journal of Marine Science 23(2): 1-9 [doi: 10.4314/wiojms.v23i2.1]

Received:
January 1, 2024

Accepted:
April 17, 2024

Published:
September 11, 2024

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Abstract

Mangrove forest ecosystems provide essential services to tropical coastal communities, including as a source of food, fuel and building materials. During the Covid-19 pandemic human movements were restricted at all levels, including locally in coastal communities. The impact of these measures on marine ecosystems such as mangroves were not well understood. A household survey was conducted in a mangrove-dependent community at Mtwapa Creek to evaluate their perceptions on the rate of mangrove degradation, factors contributing to mangrove degradation, and species that were most exploited during the pandemic period. Multiple Correspondence Analysis (MCA) was used to determine the association of Covid-19 with economic activities. Due to the restrictions on human interactions and travel during the pandemic, some natural ecosystems thrived, but in contrast accelerated destruction of mangrove forests occurred along Mtwapa Creek. The MCA indicated significant association between mangrove degradation rate and unemployment, charcoal burning, and reduced farming activities. A Chi-square test confirmed significant degradation of mangrove forests. Loss of income sources during the pandemic led to an increase in exploitation of *Rhizophora mucronata, Ceriops tagal* and *Avicennia marina*. These species were mainly harvested for construction and charcoal burning. Mangrove management measures could not be effectively enforced during the pandemic.

Keywords: Post Covid-19 pandemic, mangrove conservation, mangrove degradation, Mtwapa Creek, tropical coastal communities

Introduction

The infancy of Covid-19 virus was characterised with increased frequency of human infection and life losses. Within the first four weeks, about three million infections and 200, 000 deaths were reported worldwide (CCSA, 2020) which proliferated tension for human interaction at local, national, and international scale (Nicola *et al.,* 2020). As a result, measures to control human movement and social gatherings were effected (Diffenbaugh, *et al*., 2020) leading to economic disruption as well as ecological impacts (Nicola *et al.,* 2020; Akinsorotan *et al.,* 2021). Whereas humanity endured physical and emotional health impacts, some ecological systems were observed to recover. Stokes *et al,* (2020) in their succinct report observed that the measures implemented by governments during the pandemic resulted to an increase of inland fisheries in 79 countries. Also, due to limited industrial activities and minimal travels by road, air and sea, a reduction in the emmissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) was observed (CCSA, 2020).

As part of the ecological systems on coastal shorelines located in tropical regions, mangrove forests are important carbon sequesters. In the global perspective, mangroves have a sequestration capacity of 21 gigatons

of CO_2 (Mark and Marice, 2021) providing the basis for climate change mitigation measures (Chow, 2017). Mangrove root systems are nesting and breeding habitats for juvenile fishes (Gambo *et al.,* 2019). A thriving mangrove forest increases the small-scale fisheries productivity for the wellbeing of the dependent local communities through provision of protein and income. Mangroves have other socio-economic benefits which include medicinal and chemical uses, fodder for livestock and food for humans. Nevertheless these ethnobiological uses of mangroves have been reported to reduce over time (Dahdouh-Guebas *et al.*, 2021). Despite these benefits, mangrove forests are under pressure worldwide (Kairo *et al.,* 2002). The decline in mangrove forests is associated with increased human settlement in coastal areas and exploitation of mangrove products for timber, construction, fuel wood, and agriculture (Romañach *et al.,* 2018; Dahdouh-Guebas *et al.,* 2000).

In order to protect mangrove ecosystems from overexploitation, the Government of Kenya has established several management measures. Mangrove forests are protected by the Kenyan law as natural resources. All mangroves in Kenya are designated government reserve forests under the Legal Notice No. 174 of 1964 (Government of Kenya, 2017). The Forest Conservation and Management Act of 2016 provide funds for management and conservation of forests including mangrove forests. Such management should safeguard sustainable development through participation of local communities (Government of Kenya, 2016b). In addition, the Wildlife Conservation and Management Act of 2013 as well as the Fisheries Management and Development Act of 2016 ensure sustainable exploitation of mangrove forests. Also, non-government actors such as the World Wide Fund for Nature (WWF) and Western Indian Ocean Marine Science Association (WIOMSA) contribute immensely in management and conservation of natural resources within East Africa. They support local communities and civil society organisations mainly through funding efforts in natural resources management and conservation, restoration of degraded ecosystems, community sensitization on sustainable exploitation of natural resources, advocacy and campaigns for policy change and capacity building (Prosperi *et al.,* 2021).

The impact of anthropogenic activities on aquatic and terrestrial ecosystems has been a subject of many scientific studies (Dzoga *et al.,* 2019; Mark and Marice, 2021) especially during the Covid-19 pandemic era. However, there is limited information on the state of mangrove ecosystems during this period. Like in many parts of the world the Kenyan population encountered restrictions on human interactions, movement, and social gatherings during this period. As much as these measures improved the wellbeing of humanity, their implications on community dependent ecosystems like mangrove forests were not well known. To fill this gap, the Mtwapa Creek mangrove ecosystem community in particular was selected for this study to determine the status of the mangrove forest after the Covid-19 pandemic. Based on these findings, the current work recommends measures which could be implemented in order to protect mangrove ecosystems and other natural resources during pandemics.

Materials and methods

Study area

Mtwapa Creek is located in Kilifi south sub-County at Latitude -3.886234S and Longitude 39.675178E (Fig. 1). The creek is about 13.5 km long and borders the Indian Ocean (Mutua *et al.,* 2004). The patches of mangrove forests in the area are named after the adjacent villages; namely Lutsanga, Kidutani and Timbetimbe. The creek is fed by three seasonal streams (i.e., Ndovu, Kashani and Kidutani). In Kenya, there are nine species of mangroves of which eight species are located within the study area (Mirera and Mtile, 2009). Lutsanga, Kidutani, and Timbetimbe villages have a population size of 495, 815, and 470, respectively. The three villages are within Mtwapa sub-County with a population size of 127, 377 people (Government of Kenya, 2019).

Sample size and sampling procedure

Purposive sampling was applied to select Lutsanga, Kidutani, and Timbetimbe villages for this study within the the Mtwapa Creek mangrove forests ecosystem. The Cochrans formula for infinite population size ($z = 1.96, e = 0.05, p = 0.5, q = 1 - 0.5 = 0.5$) was used to estimate the initial sample size which generated 384 required participants. Based on the actual population size of the three villages (495, 815, and 470), the sample size was then corrected with Cochrans correction formula (n = new sample size, n_0 = initial sample size, N = actual population of the villages) for small sample sizes. Hence a final sample size of 316 participants was used. Proportional samples for each village were determined by the ratio of population size of each village divided by the overall population of the three villages, then multiplied by 316. Thus the respondents for Lutsanga, Kidutani, and Timbetimbe were 88, 145, and 83, respectively. Data was collected through semi-structured interviews using questionnaires

designed to gather information on economic activities, household size, factors hindering mangrove conservation, estimated income of the respondents and types of mangrove species exploited among other variables. Respondents for the semi-structured interviews were selected through a simple random process.

(MCA) was performed to determine the association between degrees of mangrove degradation with economic activities. The Chi-square test was conducted to determine the significance level of mangrove degradation during Covid-19.

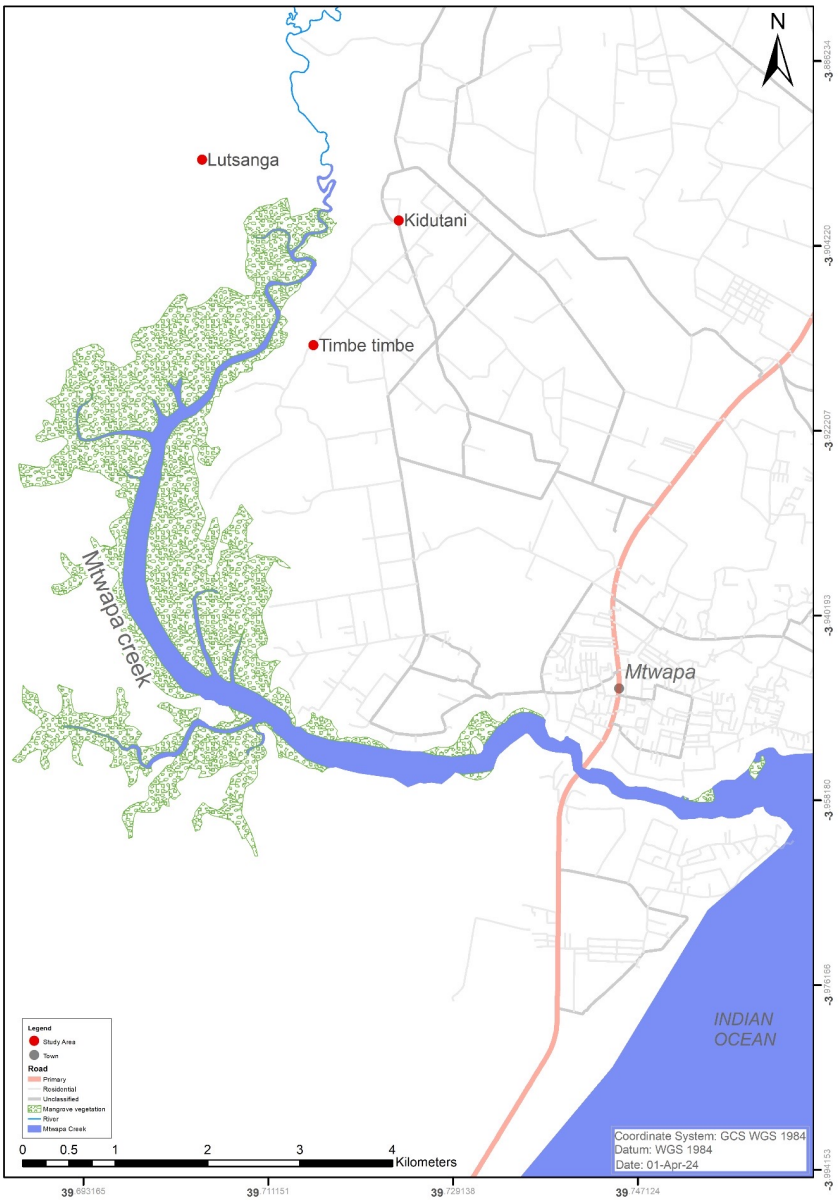

Figure 1. A map of Mtwapa Creek showing the distribution of mangroves from the mouth and upper parts of the creek and the study sites of Lutsanga, Kidutani and Timbetimbe.

Data analysis

Frequency distribution of variables was determined by SPSS v16 software. Microsoft Excel was used for descriptive statistics on mangrove species exploitation and factors that hinder mangrove conservation and restoration. Multiple Correspondence Analysis

Results

Income categories of mangrove dependent communities

As indicated in Figure 2, the majority (35 % and 29 %) of the Mtwapa Creek community were earning less than USD 35 per month. Only 2 % of the residents

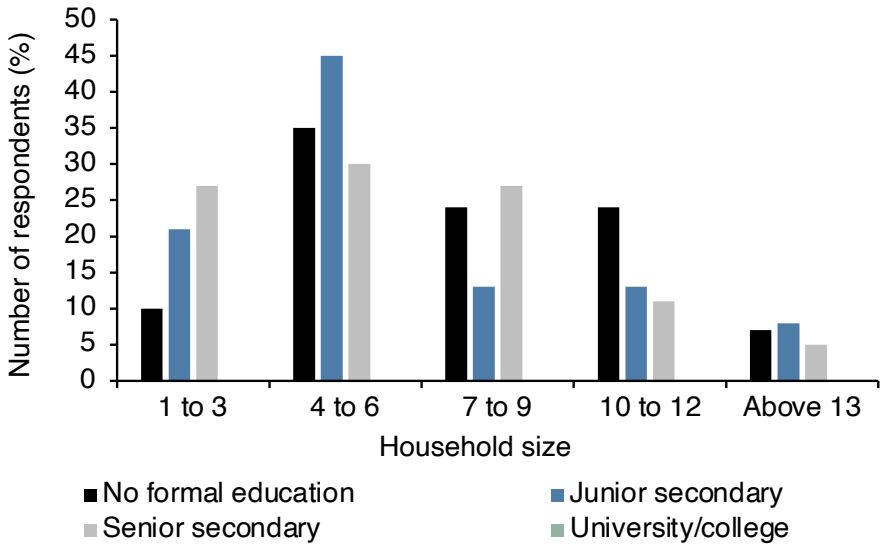

Figure 2. Comparison between household size and level of education attained.

earned above USD 140 per month. Across all the household sizes with an exception of household size of 7 to 9 members, most community have attained junior secondary education while others have no formal education (Table 1).

Status of mangrove degradation during Covid-19 era

The degradation of mangrove forests was observed to be highest during the Covid-19 period by the majority (84 %) of the mangrove dependent community (Table 2).

About 11 % of the residents reported inadequate knowledge of mangrove exploitation. For these residents, they reported to have no direct contact or interaction with mangroves in the study area. Their interaction with mangroves was mainly through use of mangrove products e.g., timber, charcoal and firewood. These products are sold within the study area as well as in the nearby commercial centers in Kilifi and Mombasa. Mtwapa Creek depicted widespread mangrove degradation as indicated in Figure 3.

Levels of association of mangroves degradation with economic activities during the Covid-19 period

As shown in Figure 4, a high rate of mangrove degradation (Covid-19-impact-High) was highly associated with unemployment, charcoal burning, selling firewood, fishing and lack of farming economic activities. A moderate rate of mangrove degradation (Covid-19-impact-Moderate) was highly associated with farmers and employed people, and those who did not participate in charcoal burning, fishing, and selling of firewood. Results of the Chi square test showed significant levels of mangrove degradation during the Covid-19 era (χ = 1093.9, P < 0.05).

Table 1. Income categories of the mangrove dependent community in Mtwapa Creek.

Estimated monthly income (USD)	Frequency	Percent (%)
Below 7	90	29
7-35	109	35
35-70	75	24
70-105	25	8
105-140	5	2
Above 140	12	2
Total	316	100

Table 2. Status of mangrove degradation during Covid-19 period in Mtwapa Creek, Kilifi County based on perceptions of respondents during the study.

Degree of mangrove degradation	Frequency	Percent (%)
High	266	84
Moderate	9	3
Low	5	2
Do not know	36	11
Total	316	100

Levels of mangrove species exploitation in Mtwapa Creek

The mangrove species *Rhizophora mucronata* was observed to be the most exploited mangrove species followed by *Ceriops tagal* and *Aveccinia marina*. The least exploited species were *Heritiera littoralis* and *Brugeuira gymnorrhiza* (Fig. 5).

Factors affecting mangrove conservation in Mtwapa Creek

The majority of the mangrove dependent community indicated lack of funding, insufficient knowledge and skills, insecurity, and lack of government support as the greatest challenges impeding mangrove conservation efforts (Fig. 6).

Figure 3. Status of mangrove degradation at Mtwapa Creek in Kilifi County, Kenya.

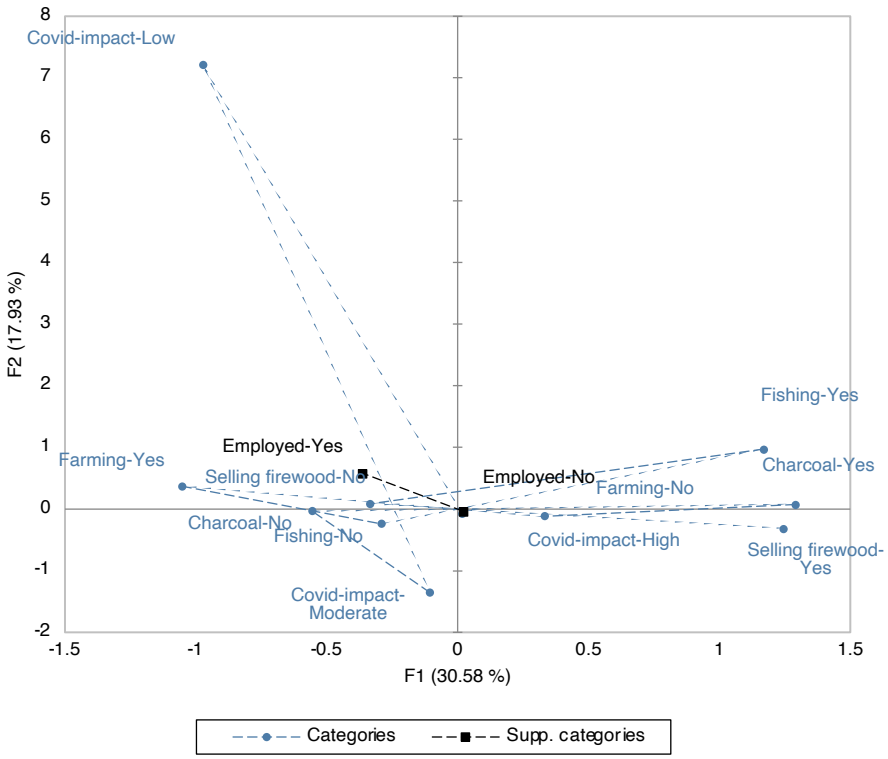

Figure 4. Multiple Correspondence Analysis (MCA) indicating association of the rate of mangroves degradation during the Covid-19 period with economic activities. Categories (axes F1 and F2: 48.51 %).

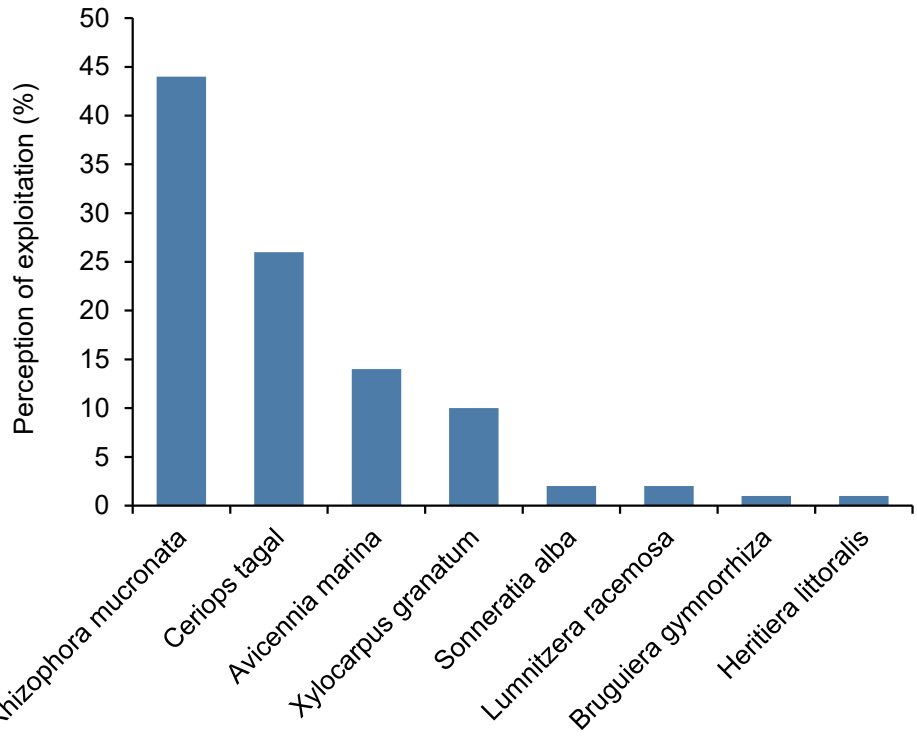

Figure 5. Perceptions of degree of exploitation of mangrove species at Mtwapa Creek over the study period.

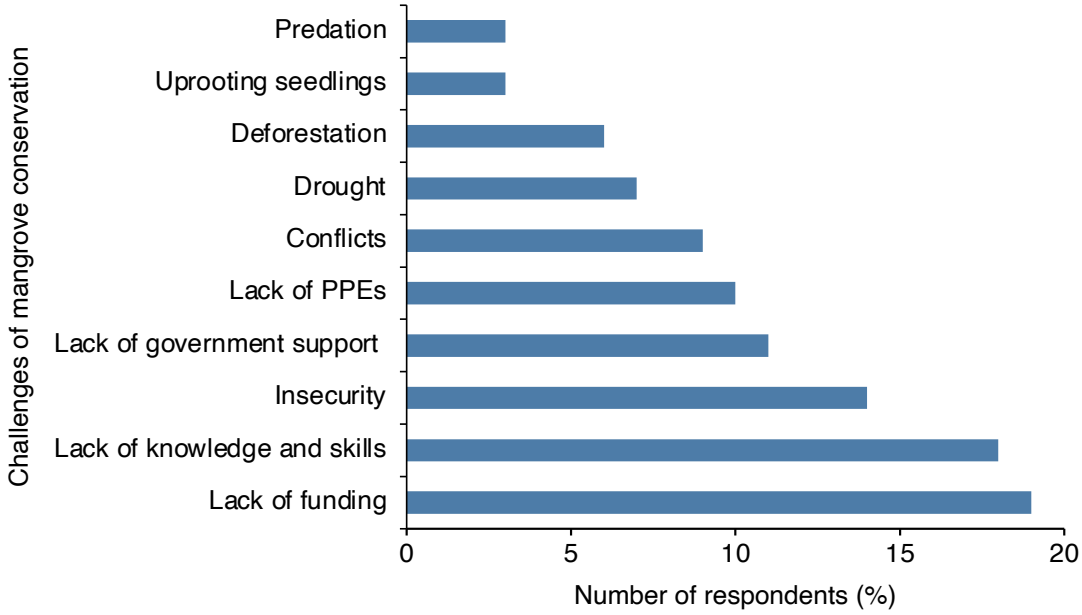

Figure 6. Challenges facing the mangrove dependent community for mangrove conservation at Mtwapa Creek in Kilifi County, Kenya over the study period.

Discussion

Dwindling mangrove forest ecosystems has been observed in many coastal countries globally (Das *et al.,* 2020). Degradation of mangrove forests is intricately connected with natural and anthropogenic factors (Romañach *et al.,* 2018). While natural factors are more pronounced and widely studied with regards to mangrove forest deterioration (Paul *et al.,* 2017), human interventions play a critical role in restoration and conservation of these ecosystems. Anthropogenic factors have, however, caused severe destruction to mangrove ecosystems. The destruction of mangroves is associated with economic activities including charcoal burning, cutting of wood for fuel, fishing, and unemployment (Mark and Marice, 2021). This study has shown that man-made activities accelerate the destruction of mangroves forests. In Mtwapa Creek, the mangrove forest ecosystem is a source of livelihood for most residents. Most of the residents lack professional education necessary for stable jobs from the government and private sector (see Fig. 2). Thus, they sustain their livelihoods from casual work e.g., fishing, and charcoal burning. Unemployment and lack of stable income as well as lack of entrepreneurial knowledge and skills have increased reliance on mangrove resources by the majority of Mtwapa Creek residents.

The Covid-19 pandemic period led to not only loss of human lives but also to dwindling of economic fortunes. As humanity suffered, the natural resources such as fisheries were reported to flourish (Akinsorotan *et al.,* 2021). Contrary to this, mangrove forest ecosystems experienced immense destruction as shown in this study. The restriction on movement, social gatherings, and prolonged lockdowns led to loss of sources of income and increased frequency of human illness (Ede *et al.,* 2021). This intensified mangrove forest destruction for charcoal burning and selling of wood fuel.

Legal frameworks and regulations are important in the management of natural resources such as mangrove forests. While these frameworks outline procedures for management and conservation of mangroves and associated resources (Government of Kenya, 2013, 2016a, 2016b), their enforcement and implementation were a challenge especially during the pandemic period. Priorities over this period changed to support the wellbeing of humanity over natural resources. Natural resources became a means for prosperity as well as survival, resulting to overexploitation. This condition was aggravated by lapses in organisations mandated to manage natural resources. However, this observation is contrary to a study by Akinsorotan *et al.,* (2021) which indicated progressive protection of the natural resources across the globe. This study has observed that there was minimal government support to residents in terms of monitoring, enforcement of

regulations and financial aid. While sustainable natural resource management is effective through the involvement of the community (Hamza *et al.,* 2023), the lack of government support during the pandemic was indicated by most residents as among the major challenges for mangrove forest restoration and conservation during this period.

Protection of mangrove species is critical not only for the health of marine and coastal ecosystems but also for human nutrition and health. *Rhizophora mucronata, Ceriops tagal and Aveccinia marina* were the most exploited mangrove species. These species are the most dominant and abundant in Kenya. They are exploited mainly for construction, wood fuel and charcoal burning. As currently indicated, their exploitation rates exceed their regeneration. This will ultimately hinder the ecosystem services. Therefore, urgent restoration and conservation measures should focus on the selection of these species for planting and re-planting. Furthermore, there is a need to train and instil skills and knowledge to members of the Mtwapa Creek community on mangrove forest conservation, restoration and sustainable exploitation. This would enhance restoration and conservation measures. Since the exploitation of mangroves is mainly for economic reasons, provision of alternative sources of livelihoods to residents (especially during pandemics) will be vital in the conservation and restoration efforts.

Conclusions

Mangrove degradation in Mtwapa Creek is a result of anthropogenic factors rather than environmental conditions. During the Covid-19 period, mangrove degradation was highly associated with charcoal burning, unemployment, and lack of alternative sources of livelihood such as farming. The mangrove dependent community of Mtwapa Creek are characterised by low-income earnings of less than USD 7 per month. Low level of income earnings coupled with limited alternatives for livelihoods during the pandemic period compelled the local community to rely on charcoal burning as the main source of income. As a result, the mangrove forest of Mtwapa Creek was highly degraded during this period. Restoration and conservation measures have not been successful due to the lack of government support in terms of monitoring and financial provision. Furthermore, lack of knowledge and skills to manage mangrove forests has led to continuous degradation. Frequent monitoring, financial support, provision of alternative livelihoods, especially during pandemics, and training on mangrove skills and knowledge will be critical in reviving the mangrove ecosystems of Mtwapa Creek in Kilifi County, Kenya.

Acknowledgements

This work was funded by the Institute of Research, Innovation and Extension (IRIE) of the Technical University of Mombasa (TUM) as an award of research grant number TUM/PRI/IRP/22-23/VOL.4/25 (73). Research permits were obtained from National Commission for Science, Technology, and Innovation (NACOSTI) No. 264869 and TUM SERC EXT/002/2023. We wish to give our sincere thanks to the management of Technical University of Mombasa for their support.

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