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The effect of anthropogenic disturbances on population structure and regeneration of *Scorodophloeus fischeri* and *Manilkara sulcata* in coastal forests of Tanzania

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Scorodophloeus fischeri (Fabaceae, subfamily Caesalpinoideae) and *Manilkara sulcata* (Sapotaceae) are examples of tropical African hardwood species and are endemic to East African coastal forests. These plant species are threatened by human activities beyond natural recovery in some forests. This study aimed to assess the effects of anthropogenic disturbance on the natural regeneration potential of *S. fischeri* and *M. sulcata* in the selected coastal forests of Tanzania. Transects were established in various vegetation communities and a nested quadrat technique was used to assess the natural regeneration. *Scorodophloeus fischeri* regenerates best in Zaraninge forest with high density of trees with diameter at breast height (DBH) between 10–50 cm and a higher seedling density than in other forests. Similarly, *M. sulcata* regenerates best in Pande forest, although many trees had a DBH of 10–30 cm, implying that the trees with size classes above these are missing. It was concluded that the minimum level of human disturbances in Zaraninge favoured high potentials of natural regeneration of S. *fischeri.* Disturbances through human activities contributed to the variation in the natural regeneration potentials for *S. fischeri* and *M. sulcata* in these forests. Conservation attention is likely to improve population structure and natural regeneration patterns of *S. fischeri* and *M. sulcata* in East African coastal forests.

Keywords: anthropogenic disturbance, coastal forest, DBH size class distribution, natural regeneration

Introduction

Tanzanian coastal forests are part of 34 global biodiversity conservation hotspots (Myers et al. 2000). However, resources from these forests are harvested by intimately forest resource dependent, poor rural communities for their daily livelihoods and commercial gains. Harvesting of the forest products is unsustainable, which disturbs the natural forests and makes their future existence rather uncertain. Anthropogenic activities in these forests such as fire, clearing of forests for cultivation, harvesting of woody species for fuel, production of charcoal, building poles, timber and traditional medicine causes disturbance that contribute to degradation and loss of plant species. Pickett and White (1985) defined disturbance as 'any relatively discrete event in time that disrupts population structure, changes resources and the physical environment.' The effects of a disturbance depend not only on the type and magnitude of the disturbance, but also on its timing and frequency of recurrence. The human population in villages and towns close to the coastal forests is increasing at high rate (Table 1). The need for woody resources and products from the coastal forests increased, which result into degradation and consequently result in an irreversible ecological change and genetic loss. As a result of widespread exploitation pressure, many local and regional endemic plant species are affected.

Scorodophloeus fischeri (Taub.) J.Leonard (Fabaceae, subfamily Caesalpinoideae) and *Manilkara sulcata* (Engl.) Dubard (Sapotaceae) are examples of tropical African hardwood species that are endemic to the East African coastal forests. *Scorodophloeus fischeri* occurs in the coastal forests of the southern part of Kenya (Brenan 1967), in coastal forest fragments in Tanzania up to the foothills of the Eastern Arc Mountains, and in forest fragments in the northern part of Mozambique (Temu 1988). This species may be widely distributed on the ridge tops and plateaus in one forest or steep slopes in another forest fragment. *Scorodophloeus fischeri* requires moist habitats and micorrhizal associations to successfully regenerate. This means distribution and regeneration of *S. fischeri* depends upon a combination of variation in habitat conditions and ecological interactions occurring within coastal forests. *Manilkara sulcata* occurs particularly along the Indian Ocean coastal belt from the coastal Horn of Africa through the east coast of Kenya, Tanzania and northern part of Mozambique. *Manilkara sulcata* is a light-demanding species and occurs on the ridge tops of these coastal forests and areas with free-draining soils on eastern and western slopes of the hills. *Manilkara sulcata* and *S. fischeri* are the most targeted and highly exploited in the coastal forests because of their suitability in all sizes for building poles, fuel wood and charcoal making, which have

Table 1: Human population growth in the Dar es Salaam and Coast regions (Tanzania Bureau of Statistics)

Town	Population increase with time (years)			Rate of population increase per year	
	1978	1988	2002	1978–1988	1988–2002
Dar es Salaam region	843 090	1 360 850	2 497 940	51 776	81 220.7
Coast region	516 586	638 015	889 154	12 142.9	17 938.5

caused the recent severe degradation of coastal forests. The regeneration of the two species in their natural habitats has been affected owing to severe anthropogenic disturbances. However, little information exists on the impacts of human disturbance on the natural regeneration potential of *S. fischeri* and *M. sulcata* in coastal forests. Analysis of the stem diameter distribution of the two species was considered useful to provide better understanding of the dynamics of tree populations under anthropogenic disturbances in coastal forests. Because of limited information on plant population characteristics in relation to disturbances in the East African coastal forests, it is difficult to predict the future of their woody species populations, communities and forest ecosystems. The objective of this study was to determine the effects of anthropogenic disturbance on natural regeneration potential of *S. fischeri* and *M. sulcata*, which are among the threatened plant species in the coastal forests of Tanzania. Although there are many coastal forests in Tanzania, we opted to study only three of these (Zaraninge, Pande and Kazimzumbwi) because they are surrounded by impoverished communities, and close to coastal cities and towns with high exploitation pressure. We opted to assess only charcoal burning, fire effects and fuel wood collections, which are the most crucial anthropogenic disturbances in coastal forests at the moment since logging ceased owing to depletion of suitable timber trees.

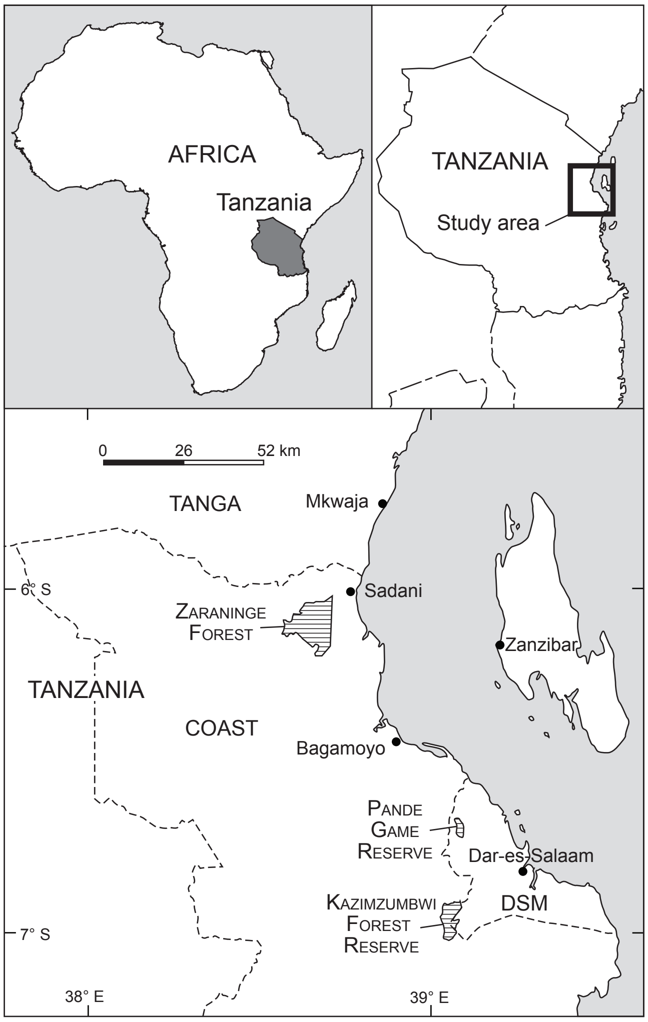

Figure 1: Location of Zaraninge, Pande and Kazimzumbwi forests in Tanzania. Source: Clarke and Burgess (2000) with slight modification

Material and methods

Description of the study area

The study area comprised Pande, Kazimzumbiwi and Zaraninge Forests, which are part of the Coastal Forest Ecosystem in Tanzania (Figure 1). The forests are found between longitudes 38°30′ and 39°6′ E and latitudes 5°40′ to 7°0′ S (Clarke and Dickinson 1995). The study area borders the Indian Ocean to the east, Tanga region to the north, Lindi region to the south and Morogoro region to the west. The climate in the coastal area is rather monsoonal with high temperatures and relative humidity in the dry and rainy seasons. The average annual rainfall is below 1 000 mm (Clarke and Dickinson 1995) with a bimodal pattern: a long rainy season from March to June followed by a short rainy season from September to November, but no month experiences appreciable rainfall (Mligo et al. 2009). The rainfall determines the luxuriant growth of evergreen patches in coastal forest fragments and thickets. A cool season prevails from June to August and a hot season from December to mid-March.

The East African coastal landscape accounts for the present habitat diversity and distribution in coastal forests and their vegetation community characteristics through their influences on physical and chemical characteristics of the soil. The continuous processes of erosion and deposition since the formation of the East African rocks culminated in the existing complex geomorphology and associated soils (Clarke and Burgess 2000). The topography of the East African coast is complex due to changes in the coastal landscape, i.e. coastal plains sloping gently upwards and away from the coast, which are interrupted by hills and valleys. The soil is sandy and varies significantly from one location within any particular forest fragment to the other and is therefore complex. The coastal forest vegetation occurs as evergreen thickets, evergreen canopy forest fragments, scrub forests, woodlands, grasslands and wooded grasslands between the semiarid zones of the Zambezi River basin and the humid forest zones in the foothills of the Eastern Arc Mountains (White 1983). However, changes in vegetation composition is caused by the effects of human activities such as fires, cultivation, charcoal burning, pole cutting and fuel wood collection and large parts of the forests are degraded.

Sampling procedures

A reconnaissance survey was carried out to identify various potential habitats in which *M. sulcata* and *S. fischeri* are normally found in three coastal forests. Six transects with mean length of 600 m were established in each of the forests making a total of 18 transects. The transect placements were stratified to ensure coverage of all disturbed areas and different habitats (with heterogeneous vegetation in each forest). A series of nested quadrats (Stohlgren et al. 1995) were systematically established at 100 m intervals along transects in each forest covering a total sample area of 1.8 ha. The quadrats were positioned on alternating sides of the transect following the method by Kasenene (1987). The following quadrat sizes were used: (1) 25 m × 20 m was used for sampling of trees with >10 cm stem diameter at breast height (DBH) including *M. sulcata* and *S. fischeri*; (2) 5 m × 2 m quadrats nested in the larger quadrat for shrubs and regeneration (seedlings, saplings and coppices) of *M. sulcata* and *S. fischeri*; and (3) 2 m × 0.5 m quadrats nested in the 5 m × 2 m quadrats for the herb layer. Tree seedlings were plants of <2 cm diameter and saplings were plants of 2–4 cm diameter as recommended by Luoga et al. (2002) and Lejju (2004). Poles were stems of 4–10 cm DBH but were not considered for analysis because poles of the two study species were among the most exploited resource from coastal forests. The recorded data were insufficient to present the argument about effects of anthropogenic activities on regeneration pattern in disturbed forests. The number of coppicing shoots (resprouts) of all sizes from each stump of *M. sulcata* and *S. fischeri* in each plot (20 m × 25 m) established along transects were enumerated and combined to form a composite sample per species. However, all data collected were a composite sample aggregate from different parts of the forest.

Assessment of anthropogenic disturbance in the coastal forests

The anthropogenic disturbances (fire, charcoal burning, fuel wood collection and pole harvesting) affecting plant communities in the coastal forests of Tanzania were qualitatively assessed in the main 20 m × 25 m quadrat, using a six-point scale (0–5) to represent the percentage of the quadrat disturbed: 0 = no disturbance; 1 = 0–20% of the quadrat disturbed; 2 = 21–40% of the quadrat disturbed; 3 = 41–60% of the quadrat disturbed; 4 = 61–80% of the quadrat disturbed; and 5 = 81–100% of the quadrat disturbed. The point scale values were assigned to each type of anthropogenic disturbance independently from the other.

Data analysis

Trees were summarised in terms of number of stems by DBH class by species and forest. Densities of trees, seedlings, coppices and saplings as well as the level of disturbances were compared using a multiple comparison (Zar 1999). Regression analysis was used to relate between levels of disturbance and seedling density in all the three coastal forests using Graphpad Instat 3.06 (GraphPad Software, San Diego).

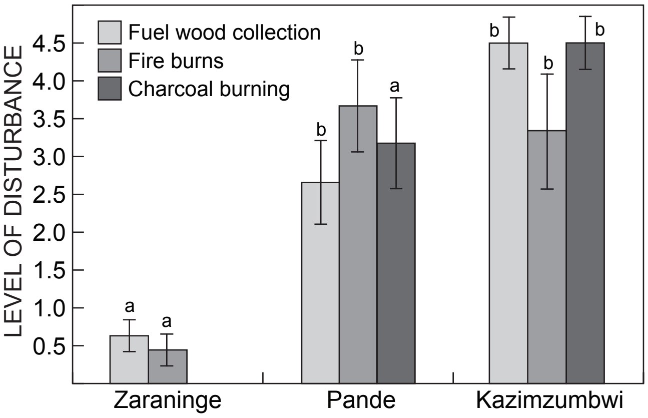

Figure 2: Mean levels of disturbance in the coastal forests, i.e. 0 = no disturbance, to 5 = 81–100% disturbance. Different letters above the bars indicate disturbance is significant at $P < 0.05$

Results

Level of disturbance in the coastal forests

Human disturbances were relatively low in Zaraninge Forest compared to the other two forests (Figure 2). The effects of fire in Kazimzumbwi and Pande forests was significantly higher than in Zaraninge Forest (LSD = 3.66, $F = 5.35$, $P < 0.01$; and LSD = 2.83, $F = 4.78$, $P < 0.01$, respectively). Fire effects in Zaraninge were particularly concentrated in the forest edges. Fuel wood collection and charcoal burning were most serious in Kazimzumbwi and Pande Forests. There was significantly lower effect of disturbance by fuel wood collection in Zaraninge Forest than in Kazimzumbwi (LSD = 3.833, $F = 9.13$, $P = 0.001$) and Pande (LSD = 2, $F = 4.76$, $P < 0.01$). Disturbance through fuel wood collection did not differ significantly between Pande and Kazimzubwi forests ($P > 0.05$). There was no sign of charcoal burning in Zaraninge Forest, but charcoal burning was severe in the other two forests and was significantly higher in Kazimzumbwi Forest than in Pande Forest (LSD = 1.33, $F = 3.28$, $P < 0.05$).

DBH size class distribution in coastal forests

The stand DBH class distribution for all tree species combined showed considerable differences between the three selected coastal forests (Figure 3). The pressure was much higher in Kazimzumbwi Forest with only a few individuals in the DBH class above 40 cm present (Figure 3). However, the few species that still exist in the forest in the higher DBH classes such as *Bombax rhodognaphalon* are unsuitable for charcoal making and other uses. The DBH class distribution for *S. fischeri* showed an inverse J-shaped curve in all three forests, which varied greatly between the forests owing to different levels of disturbance (Figure 4).

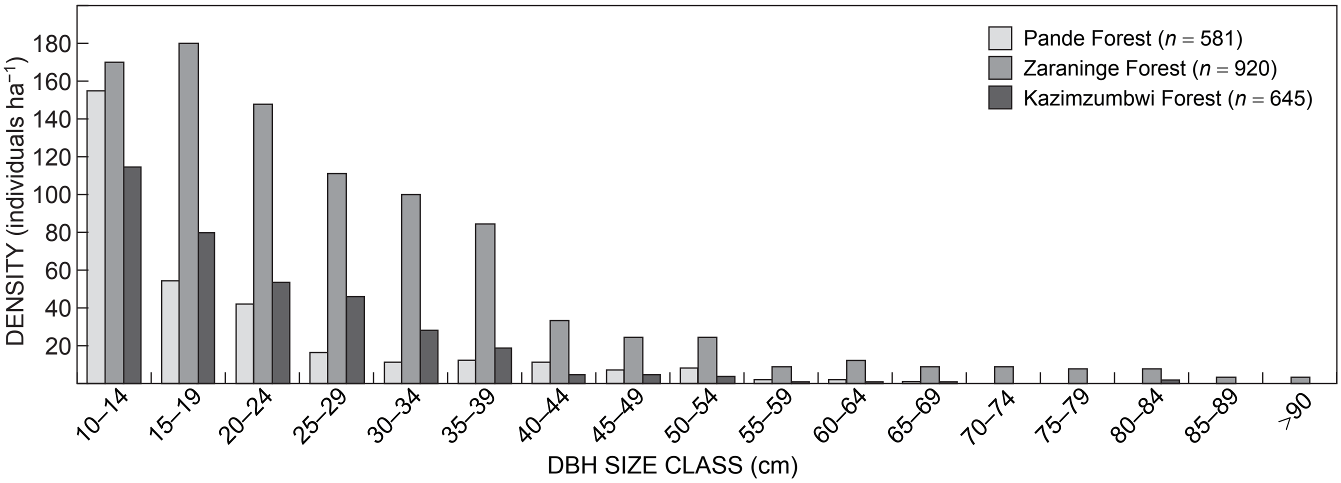

Figure 3: Diameter at breast height (DBH) class distribution of trees sampled in each of the three coastal forests

Similarly, *M. sulcata* showed a J-shaped pattern at Pande and Kazimzumbwi as many individuals were in low DBH size classes, i.e. 10–25 cm in Pande (Figure 4A) and 10–45 cm in Kazimzumbwi Forest. However, *M. sulcata* regenerates poorly in Zaraninge Forest with a bell-shaped curve where many individuals were at DBH class of 15–44 cm (Figure 4B). The bell-shaped curve showing a poor recruitment at low size classes for *M. sulcata* in Zaraninge Forest and the population is rather interrupted (Figure 4B).

Stem density and potentials of natural regeneration of Scorodophloeus fischeri *and* Manilkara sulcata *in the coastal forests*

The total stem density (stems per hectare) of *S. fischeri* trees greater that 10 cm DBH was significantly higher in Zaraninge than Pande (LSD = 167.78, $F = 11.96$, $P = 0.001$) and Kazimzumbwi (LSD = 178.89, $F = 12.75$, $P = 0.001$) (Figure 5). However, Zaraninge Forest recorded significantly lower stem density of *M. sulcata* than Kazimzumbwi Forest (LSD = 62.22, $F = 6.14$, $P < 0.01$).

Kazimzumbwi Forest had significantly lower seedling density of *S. fischeri* than Zaraninge Forest (LSD = 48 750, $F = 7.84$, $P < 0.001$) and Pande Forest (LSD = 41 250, $F = 6.634$, $P < 0.001$) (Figure 6). The trend was the same for saplings where Kazimzumbwi had significantly lower sapling density than Zaraninge (LSD = 16 250, $F = 7.84$, $P < 0.001$) and Pande (LSD = 13 750, $F = 6.63$, $P < 0.001$). However, Pande had a higher coppice density than Kazimzumbwi Forest, (Figure 6). Analysis of variance showed a significantly higher coppice density in Pande Forest than Zaraninge (LSD = 15 918, $F = 6.65$, $P < 0.001$) and Kazimzumbwi (LSD = 17 025, $F = 7.12$, $P < 0.01$).

Manilkara sulcata seedling density was significantly higher in Pande Forest than Kazimzumbwi Forest (LSD = 15 833, $F = 3.79$, $P < 0.05$). Similarly, Pande had higher sapling density than Kazimzumbwi (LSD = 5 811.1, $F = 4.19$, $P < 0.05$) and Zaraninge Forest (5083.3, $F = 3.67$, $P < 0.05$). The coppice density in Pande Forest was significantly higher than in Zaraninge (LSD = 586.11, $F = 4.85$, $P < 0.01$) and Kazimzumbwi Forest (LSD = 600, $F = 4.97$, $P < 0.05$).

Correlation between the level of disturbances and seedling density

Disturbance was negatively correlated with seedling density of *Scorodophloeus fischeri* and *Manilkara sulcata* in Kazimzumbwi Forest. The regression analysis showed significant negative correlation between seedling density with charcoal burning effects ($r = -0.95$, $p = 0.003$) and fire effects ($r = -0.905$, $p = 0.013$) (Table 2). Seedling density was significantly correlated with levels of disturbance through charcoal burning ($r = 0.87$, $p = 0.023$) and fuel wood collection ($r = 0.96$, $p = 0.0005$) in Pande Forest (Table 2). However, poor seedling establishment was observed in Zaraninge Forest with low correlation coefficients with disturbance effects (Table 2).

Discussion

Variations in levels of anthropogenic disturbance in the studied forests

The coastal forests of Tanzania are affected by human disturbance to varying degrees (Figure 2). Fire effects were more pronounced in Kazimzumbwi and Pande forests than in Zaraninge Forest. In the latter forest fire encroachment was confined to the forest edges with less effect in the inner parts. This forest has a high density of canopy trees with the conserved moist habitats in the understorey minimising the effect of fire encroachments. However, fuel wood collection and charcoal burning were the most serious in Kazimzumbwi Forest followed by Pande Forest (Figure 2). These forests have suffered from poor conservation and management such that resources have been overexploited. Owing to a high level of conservation management undertaken by the central government of Tanzania in Zaraninge Forest where the forest has been part of Saadani National Park (Antje, 2005), there was no evidence of disturbance through charcoal burning in the forest. Although Pande Forest has been affected by high levels of fuel wood collection and charcoal burning, such activities have decreased and the forest had high regeneration potential. However, such

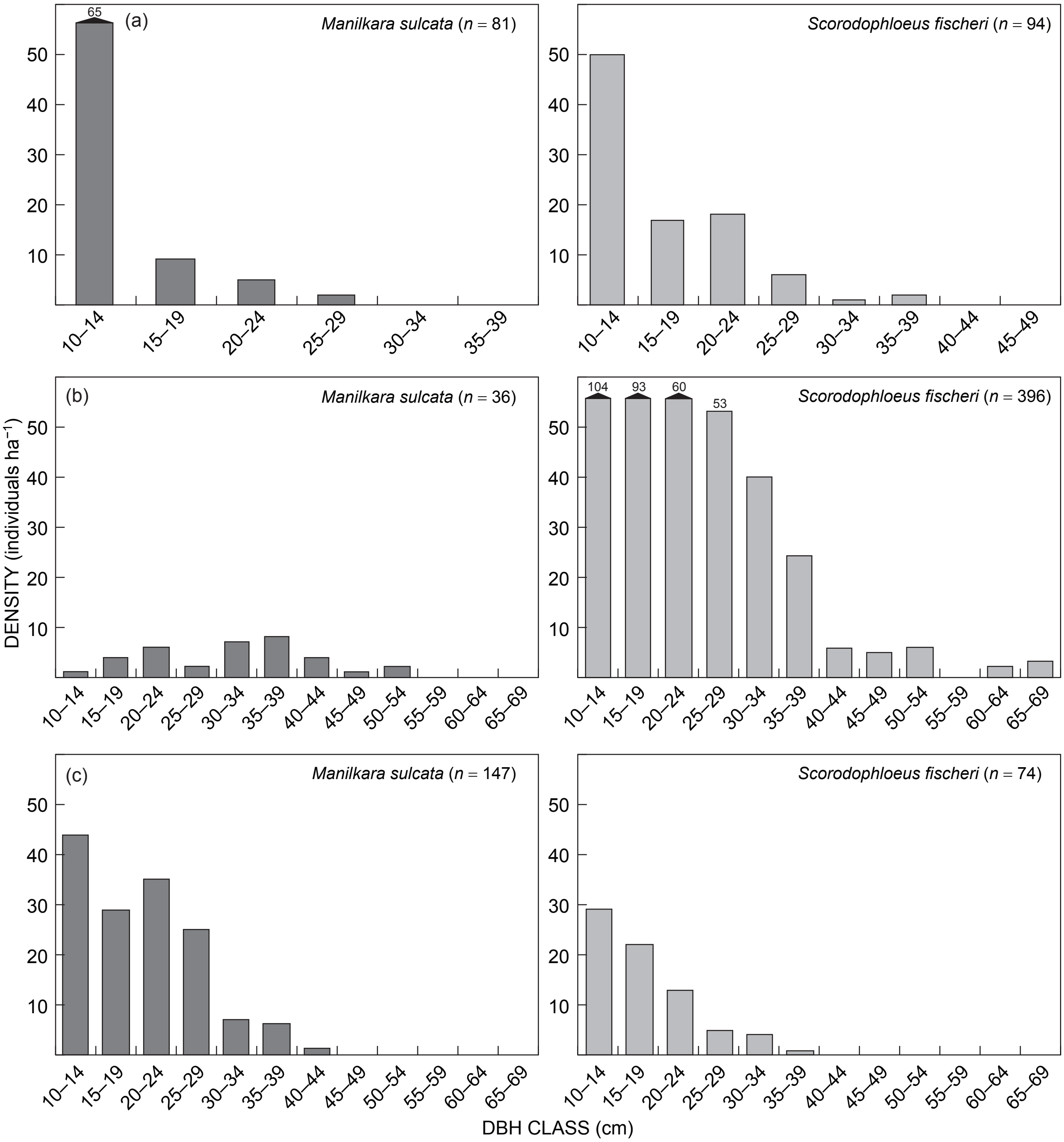

Figure 4: Diameter at breast height (DBH) size-class distribution of *Scorodophloeus fischeri* and *Manilkara sulcata* in the studied forests: (a) Pande, (b) Zaraninge and (c) Kazimzumbwi

activities have a serious ongoing impact in Kazimzumbwi Forest and large parts of the forest are being degraded because of poor management practices. The vegetation communities around these forests are dominated by *Afzelia quanzensis*, *Brachystegia spiciformis*, *Acacia* spp., *Strychnos madagascariensis* and *Spirostachys africana*, which are vulnerable to fire and uncontrolled exploitation. The forest-dependent plant species (*Manilkara sulcata*, *Scorodophloeus fischeri*, *Brachylaena huillensis*, *Baphia kirkii*, *Milicia excelsa*, *Albizia versicolor* and *Vitex zanzibarica*) are highly exploited for charcoal burning and fuel wood collection in Pande and Kazimzumbwi forests. In Kazimzumbwi Forest there is no specific species preference for either charcoal burning or fuel wood collection;

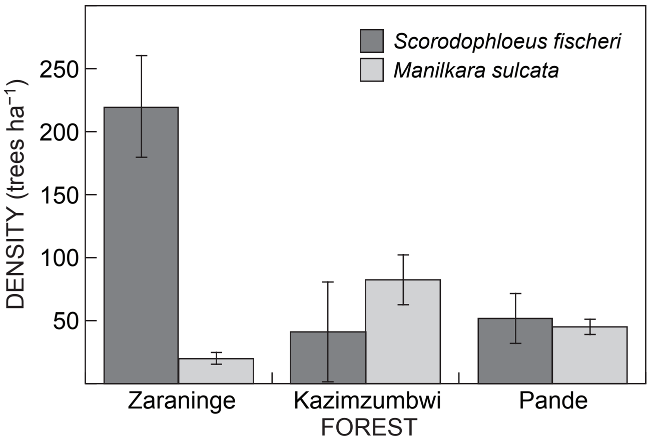

Figure 5: Total stem density of *Scorodophloeus fischeri* and *Manilkara sulcata* trees in the coastal forests

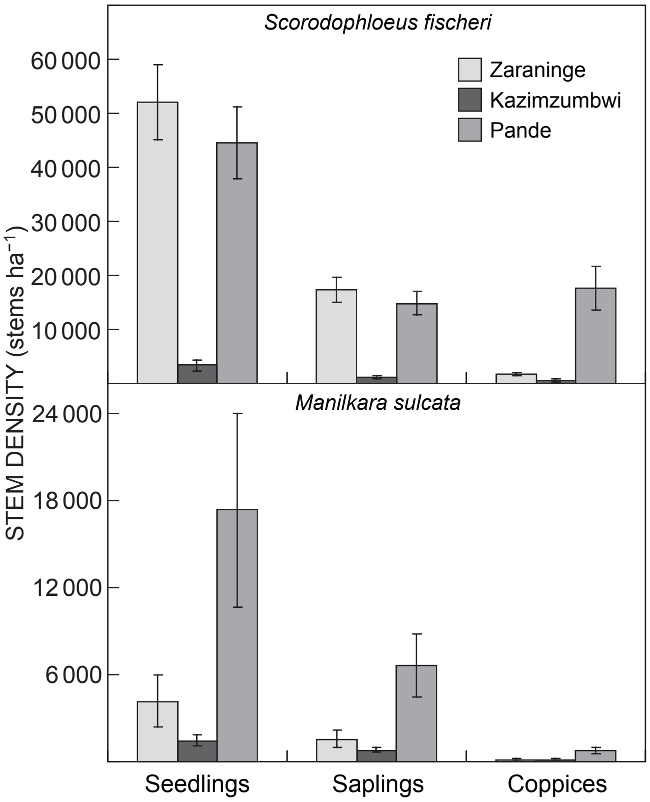

Figure 6: The natural regeneration potential of *Scorodophloeus fischeri* and *Manilkara sulcata* in the selected coastal forests

all plant species present in the forest had been exploited for either purpose.

DBH size class distribution of trees in the coastal forest

The diameter class distribution (DBH) for all trees species revealed a decrease in number of individuals with increased DBH size classes (Figure 3). Although all forests are influenced by the same climatic conditions and the soil is physically sandy, they had differences in maximum DBH size classes among them. Variations in microhabitat conditions existing among forests has an effect on performance of plants (Mligo et al. 2009), but the major contributing factor has been exploitation pressure that targeted trees of high size classes within disturbed Pande and Kazimzumbwi forests. The tree species with DBH sizes beyond these have been severely exploited for charcoal, fuel wood and poles. Kuo and Fan (2003) pointed out that individuals in small DBH classes in a given population functions as significant reserve for replacing cut-sized trees or old individuals. However, an inverted inverse J-shaped population distribution curve for *S. ficheri* in all three forests and *M. sulcata* in Pande and Kazimzumbwi forests suggested that there is still recruitment of individuals at low size classes (Figure 4). McLaren et al. (2005) pointed out that an inverse J-shaped distribution curve of plant populations indicates active regeneration. Kuo and Fan (2003) also pointed out that active regeneration is influenced by the presence of abundant reproductive trees scattered in a particular forest. *Scorodophloeus fischeri* is the most abundant in moist and shaded habitats in the coastal forests (Mligo et al. 2009). Exploitation pressure that disturbs shaded habitats might be the cause of its uneven distribution pattern in these forests. A bell-shaped population distribution curve for *M. sulcata* in Zaraninge Forest was an indication of poor recruitment at lower DBH size classes and the population is interrupted. Regardless of the nature of the DBH distribution curves for both *S. fischeri* and *M. sulcata,* they still show signs of recruitment at lower DBH classes, which can be attributed to the limited creation of large gaps. The few individuals of *M. sulcata* in large DBH classes have been a result of survival filters (such as light), which progressively limited the number of individuals to advance towards large size classes. However, the effects of exploitation pressure were more pronounced in Pande and Kazimzumbwi forests (Figure 4). This is likely to stem from the effects of exploitation for poles, fuel wood and massive removal of biomass for the purpose of making charcoal in these forests. The increased pressure is likely to deplete the reproductive individuals of the endemic plant populations causing stagnation of their regeneration pattern. According to Lyaruu et al. (2000), selective exploitation of large trees for timber, leaving behind genetically impoverished individuals causes population decline or population extinction. The impact is aggravated by the existing climate changes such that some of the remaining populations are likely to disappear from these forests due to obstacles that hinder their regeneration process. Exploitation of some individuals from these forests reduces genetic variability of populations, which decreases their ability to adjust with global climate changes in this area.

Effects of anthropogenic disturbances on regeneration potentials for **Manilkara sulcata** *and* **Scorodophloeus fischeri**

The overall stem density of *S. fischeri* was higher in Zaraninge, which is less disturbed than Pande and Kazimzumbwi forests (Figure 5). The two disturbed forests are close to human settlements and have been subjected to heavy exploitation pressure resulting in lower tree density than in Zaraninge. According to Swaine (1992), increase in fire effects and other disturbances tend to increase

Table 2: Correlation coefficients between forms of disturbances and seedling density in the three forests studied

Forest	Charcoal production		Fire effects		Fuel wood collection	
	r	*p*	*r*	*p*	*r*	*p*
Pande Forest						
Scorodophloeus fischeri seedlings	0.87	0.023	0.679	0.209	0.96	0.0005
Manilkara sulcata seedlings	0.35	0.487	0.09	0.88	0.11	0.81
Kazimzumbwi Forest						
Scorodophloeus fischeri seedlings	−0.95	0.003	−0.905	0.013	−0.64	0.169
Manilkara sulcata seedlings	−0.32	0.53	−0.29	0.57	−0.39	0.44
Zaraninge Forest						
Scorodophloeus fischeri seedlings	0		−0.528	0.28	0	
Manilkara sulcata seedlings	−0.90	0.021	0.18	0.727	0.59	0.209

the proportional contribution of vegetative reproduction. However, in all forests covered in this study regeneration through vegetative means was lower than that through seedling establishment. Exploitation of trees for fuel wood quickly brings about apparent irreversible changes in the species composition and physiognomy (Lieberman and Li 1992). The disturbed Pande and Kazimzumbwi forests are replaced by dense thickets that are further stabilised by continued cutting of trees for charcoal and fuel wood collections. Most of the clumping thickets had different plant species composition due to both selective and non-selective exploitation of woody species. Also the disturbed parts of the forests have become open to pioneer species other than native plant species. Kuo and Fan (2003) observed the pioneer tree species *Trema orientalis* to be restricted to open forest gaps. Anthropogenic disturbances in Pande and Kazimzumbwi forests created gaps that have been colonised by *T. orientalis*. Nunamaker and Valachovic (2007) pointed out that natural regeneration of the disturbed parts of the forest can result into a new forest with undesirable plant species composition. The colonising characteristics of pioneer species competed successfully against forest-dependent plant species for resources in most parts of the disturbed forests. Large-scale disturbance of the formerly naturally forested areas of an ecosystem encourages the regeneration of pioneer species that have high resource requirements from the environment (Mligo 2010). This allows large proportions of the degraded area in Pande and Kazimzumbwi forests to be covered by *T. orientalis.*

The natural potential of plant species to regenerate represents a crucial factor for conservation and management of degraded forests. Seedlings, saplings and coppices were regarded as indicators of the potential for natural regeneration of *S. fischeri* and *M. sulcata* in coastal forests. These are among the many coastal endemic plant species and are highly exploited in the forests that are closer to human settlements. Their vulnerability to disturbances threatens their regeneration in their natural locality in these forests. Although there was high density of *S. fischeri* and *M. sulcata* saplings and seedlings in their populations, the survival rate of these size classes is low due to disturbances that led to low tree densities (Figure 6). High density of seedlings in the three forests highlighted the importance of propagules in determining the composition of early successional communities and indeed their establishment and the forest community dynamics. Zaraninge Forest had the highest regeneration potential of *S. fischeri*, which was attributed to a low level of anthropogenic disturbances, favourable habitats and relatively high abundance of mature individuals. The correlation coefficients between levels of disturbance and seedling density were low, which implies that disturbance in Zaraninge Forest has very little effects on seedling density. The only disturbance due to fire effects on seedling density of *M. sulcata* and *S. fischeri* in Zaraninge Forest was on the forest edges. The potential for recovery in the Pande forest might have been owing to halting illegal exploitation pressure, fire controls and change in the forest management regimes. The levels of disturbance were positively correlated with the current density of seedlings in the Pande forest (Table 2), implying that such levels favour the establishment of seedlings in this forest. *Scorodophloeus fischeri* chiefly regenerates successfully by means of seeds under favourable conditions and in shaded habitats (Mligo et al. 2009). Nunamaker and Valachovic (2007) reported that natural regeneration from seeds requires adequate seed production, successful germination and seedling growth. The shaded habitats in undisturbed Zaraninge Forest had higher *S. fischeri* seedling density than the disturbed Pande and Kazimzumbwi forests. *Scorodophloeus fischeri* belongs to subfamily Caesalpinoideae, of which most members are ectomycorrhizal (Newbery et al. 1988). Seed germination of *S. fischeri* accelerated with an association of plant species with mycorrhizal fungi and moist conditions. Anthropogenic disturbance that involves removal of canopy trees exposes the soil to direct heating by the sun and the soil moisture disappears due to evaporation leaving the ground desiccated. The dry habitats become unfavourable for mycorrhizal association and hence regeneration of mycorrhizal plants fails. The shaded habitats preserve sufficient conditions suitable for mycorrhizal association and enable the germinating seeds of *S. fischeri* to successfully become established. Therefore degradation involving the removal of canopy trees disturbs shaded habitats, which threatens the natural regeneration of *S. fischeri* from seeds.

Conclusion

The selective exploitation of large trees in the disturbed coastal forests for charcoal, fuel wood and poles resulted in low densities of *S. fischeri* and *M. sulcata* trees. Owing to variation in levels of anthropogenic disturbance, it resulted in differences in plant population structures. There was higher regeneration potential of *S. fischeri* in Zaraninge Forest than in the Pande and Kazimzumbwi forests because of ongoing disturbance in the latter two coastal forests. Disturbance at Kazimzumbwi and Pande can be regarded as a seedling recruitment limiting factor that can exert a dramatic effect on the regeneration pattern of *S. fischeri* and *M. sulcata* trees. This is because the habitats from which *S. fischeri* could regenerate best from seeds have been destroyed through disturbance such that germinating seed cannot establish to replace the harvested adult trees. On the other hand, there was a high density of *M. sulcata* saplings and seedlings in the Pande Forest implying that this forest is recovering from previous exploitation pressure. Owing to the increased human settlements close to coastal forests, the level of disturbance has increased because of dependence for fuel wood, charcoal and poles from these forests. It is foreseen that increased conservation management through a participatory approach will minimise levels of disturbances and make exploitation more sustainable instead of the present high rate of unsustainable harvesting of these forest resources. Various alternative sources of income, building poles and energy for domestic use by people closer to these coastal forests need to be made available to enable the coastal forests to recover through natural regeneration processes.

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