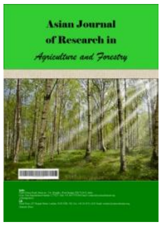

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Relationship Underlying Seedlings Composition and Abundance of Mature Tree Species at Coral Rag Forest of Mnarani Ruins

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Authors' contributions

This work was carried out in collaboration among all authors. Author MJK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JMJ and MAS managed the analyses of the study. Author MAS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The tropical regions have a rich diversity of tree species which provide the basis for a number of different forms and scales of economic activity. This study therefore was conducted with an aim of enhancing the knowledge of tree species diversity (seedlings and mature trees), and their relationship at the site. The experiment was laid out in three transects and quadrants in the forest: for mature trees the transects measured 100 m by 20 m, whereas for the seedlings quadrants measured 5 m by 5 m. That is along the ocean (T1), along human settlement (T2) and along the forest path (T3). Data was collected by counting mature trees species and seedlings. Data was analysed using R software 3.4.4 and results showed that a total of 22 tree species were recorded in the forest. In T1, the highest (22) species richness was recorded with 4 tree species restricted to the site (*Bourellia nemoralis*, *Flueggia virosa*, *Turraea wakefieldii* and *Eryithrinia abyssinica*). *Combretum schumanii* was most abundant in mature trees (89) followed by *Lecaniodiscus fraxinifolius (36)*, *Ochna thomasiana* (21) and *Adansonia digitata* (14). All the above abundant species except *Adanosnia digitata* (2) were also abundant in seedlings with (189), (11) and (21)

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seedlings respectively. In T2, 9 tree species were recorded. *Azadirachta indica* was the most dominant in both mature trees (40) and seedlings (261) while *Sterculia appendiculata recorded the lowest* (1) and (0) respectively. T3 was rich with three exotic tree species namely *Delonyx regia*, *Azadirachta digitata* and *Lannea schweinfurthii*. *Lecaniodiscus fraxinifolius* was the most common with (35) followed by *Combretum schumanii* (11). While the seedlings were (23) and (67) respectively. In conclusion, it was evident that anthropogenic factors reduced species richness and the corag rag forest had more indeginous tree species and good seed recruitment.

Keywords: Anthropogenic factors; biodiversity; seedling recruitment; sustainability; replenishment.

1. INTRODUCTION

Tropical forest is the richest in biodiversity according to [1]. It is found between the Tropic of Cancer and the Tropic of Capricorn, 23 30' south and north of the equator, respectively, covering Africa, Mexico, Central America and South America, most of the Indian subcontinent, southern China, Southeast Asia and the northern half of Australia. The forest provides goods and services such as preservation of habitats for plants and animals [2]. These forests are categorized into four types: the tropical rain forests; the moist deciduous forests; the dry forest zones; and the upland formations [3]. Of this the dry forests account for nearly half of the world's tropical and subtropical forests [4]. Even though, in these forests anthropogenic disturbances are major threats to seed dispersal services and seedling survival leading to decline in plant community regeneration, demography and forest structure [5] in return interfering with seedling species richness and ecosystem services. Particularly because the germination and establishment of seedling of many species depends on the microclimate on the forest floor and below the canopy [6].

In Kenya tropical rain forests also include the coastal forests which are located in the coastal strip of east Africa [7]. They are composed of mangrove forests of the salt-water coasts, the forests of the mountain systems and the lowland forest patches. These forests cover four sub counties: Lamu to the North, Malindi and Kilifi in the middle and Kwale in the south including Mombasa City. The northern limits of the forests are in southern Somalia close to the Kenyan border [8]. These forests are the remnants of the East African coastal dry forests composed of high levels of endemic and endangered species [9] hence the need for conservation and restoration. In this region much of the forest studies have concentrated on the large forest reserves like the Arabuko-sokoke, Shimba-hills, Tana River nature reserves and the fragmented sacred Kaya forests [10] with limited studies undertaken on the Coral rag forests. The coral forests are sustained by thin soil layer under which lies an ancient coral reef [11]. Examples of such indigenous forests are the Gede ruins, Jumba la mtwana, Shimoni caves, Kaya Kinondo and Mnarani ruins forests. Also, Bamburi nature trail is an example of exotic coral rag forest which was used to restore a coral rag landscape after quarrying in Bamburi cement industry.

The coastal forests are of critical importance to the country: they are situated at the centre of the country's tourism industry, one of leading foreign exchange earner; they are important water catchment areas for the rivers and streams on which the local people in the coastal areas depend; and they are centers of endemism for a wide variety of globally threatened fauna and flora. These forests provide the basis for a number of different forms and scales of economic activity, which provides both food for national and international consumption. Important mainstream livelihood activities along the Kenyan coast exist in particular fishing within mangrove areas and creeks, carving, agriculture, tourism, mariculture, harvesting of medicinal plants, salt production, harvesting of mangroves and wildlife harvesting. In addition The more common goods extracted from coastal forests include fuel-wood, poles, timber, logs for carving, water, pasture for livestock, herbal medicine, butterflies, snakes and honey [8].

International interest in the Coastal forests hotspot has increased over the last three decades as the realization of its biodiversity importance and of the global crisis affecting tropical forests has deepened [8]. To this end, conservation work in the coastal forests of Kenya started way back in 1983 when a team from the International Council for Bird Preservation (ICBP, now BirdLife International) surveyed the avifauna of Arabuko-Sokoke Forest on the north coast of Kenya and drew attention to its globally threatened bird species [12]. Some of the conservation works implemented include restoration programmes. For example a restoration project was done at the Gede Ruins forest by introduction of *Azadirachta indica* A. Juss [10], which is a faster colonizing species and it performed better compared to the indigenous trees species, although they have out performed the indigenous ones. Moroever conservation studies are yet to be done fully in Mnarani ruins forest which is among the most important urban forest in Kilifi under National Museums of Kenya. Actually it is described as one of the remnants of the coral rag forest [9]. It harbours unkown genetic variation and richness that has not yet been documented. Expansion of Kilifi town and encroachment for development is a major threat to these habitats. This coral rag forest is unique habitat that needs detailed information on plant species in order to advise on conservation, restoration of species and sustainable use of the forest resources and the landscape [13]. It will also play a major role as a source of genetic material for urban landscaping. This could affect the ability of the forest to self- regenerate and subsequently affect the sustainability of the biodiversity and ecosystem services. Its aganist this back drop that the study was conducted in Mnarani ruin forest to unravel the diversity of trees species found in the ruin, composition and abundance of tree species. This facilitated in planning for conservation strategies that would preserve the small forest fragment and other biodiversity threatened by emerging socio-economical activities.

2. MATERIALS AND METHODS

2.1 Site Description

Mnarani ruins forest is located in Kilifi county and lies on a longitude of 39º51'23.27."E and latitude of 30º38'27.41"S. It is found on the south bank of Kilifi creek on northern coastline and has a close proximity to the sea. Mnarani has a moderate rainfall of (800-1000 mm) with two rainy seasons. It experiences long rains between the months of March and July and shorts rains during October and ends at December. The forest sustained by thin soil layer under which lies an ancient coral reef and is a protected site under the National Museums of Kenya.

2.2 Study Design

The study was laid in transects and quadrants. Three transects meausring 20 by 100 metres were laid along the path, along the ocean and along human settlement for mature tree species while three quadrants measuring 5 by 5 meters were laid for the seedlings respectively. This gave an experimental area of 42 sq kilometers. A survey was used as a sampling technique to incude all the tree species within the transects and quadrants.

2.3 Experiment Management

The study was carried out for two months which was approximately sixty days, that is (March and April) of 2019. This period also experiences long rains. The transects and quadrants were measured using coloured ropes for visibility.

2.4 Data Collection

Secateurs were used to cut the the fertile parts (voucher specimen) of the tree, stored in collection bags and taken to National Museums of Kenya (CFCU) for further identification using plant identification keys. Counting of the mature tree species and seedlings (<30 cm) in the transects and quadrants were conducted.

2.5 Data Analysis

Data collected was recorded in excel sheets and subjected to Analysis of Variance (ANOVA) using R software 3.4.4. Thereafter, the treatment means were compared using Tukey test at 95% significance level.

3. RESULTS

3.1 Total Number of Tree Species and their Economic Importance in Mnarani Ruin Forest

The results indicated that the forest had 22 useful tree species within which 15 species were indigenous and 7 being exotic. Furthermore, after assigning these tree species into their respective families, 13 families were identified as shown in (Table 1).

It was observed that Transect 1, supported all the 22 tree species identified. In addition four rare tree species were restricted to this transect. They were: *Bourellia nemoralis* with (2) mature trees, *Flueggia virosa* with (1) mature trees, *Turraea wakefieldii with* (1)mature trees but had no seedlings except *Eryithrinia abyssinica* had (11) mature trees with (12) seedlings as shown in (Fig. 1). In this transect the most abundant and richest tree species were *Combretum schumanii* with 89 individuals which also had the most abundant seedlings(183), followed by *Lecaniodiscus flaxinifolius* had (36) individuals with (97) seedlings. Ochna thomasiana had (21) individuals but lacked seedlings, *Adansonia digitata had* (14) individuals with (3) seedlings. *Azadirachta indica had a low number of trees but translated in a high number in* (37) seedlings , *Trichilia emetica* had (3) mature individual and possessed slightly high number of seedlings (13), (Fig. 1).

Table 1. Mnarani ruin forest tree species, their families and economic importance

No.	Tree species	Family name	Uses
1	*Combretum schumanni* Engl	Combretaceae	Important for local construction for example furniture (Indigenous)
2	*Sterculia appendiculata* K.Schum	Malvaceae	The bark is used as herbal medicine (Indigenous)
3	*Cynometra webberi* Bak. f.	Fabaceae	Its fruits are edible and important for primates (Indigenous)
4	*Delonyx regia* (Boj.Ex.Hook.) Raf	Fabaceae	It is an ornamental plant (Exotic)
5	*Adansonia digitata* L.	Malvaceae	It's a food plant, the fruits are edible (Indigenous)
6	*Ficus sychomorus* L.	Moraceae	It is an ornamental plant (Indigenous)
7	*Lanea schweinfurthii* (Engl.) Kokwaro	Anacardiaceae	The tree is a good diet for primates for example monkeys (Exotic)
8	*Erythrinia abbysinica* Lam.	Fabaceae	An important medicinal plant. The bark is boiled to treat sexually transmitted disease and stomach problems (Indigenous)
9	*Azadirachta indica* A.juss	Meliaceae	A shade giving tree and the leaves are soaked to cure respiratory diseases (Exotic and invasive)
10	*Rhizophora mucronata*. Duke	Rhizophoraceae	Prevent coastal erosion and restoration of mangrove community (Indigenous)
11	*Leucaena leucocephala* (Lam) de wit	Fabaceae	Important source of forage and fodder (Exotic and invasive)
12	*Pithecellobium dulce* Roxb. Benth.	Fabaceae	The leaves are medicinal, boiled to solves gum, tooth ailments (Exotic)
13	*Hymenia verrucosa* L.	Fabaceae	The fruits are edible and a source of hardwood (Indigenous)
14	*Ziziphus mauritiana* Kuntze.	Rhamnaceae	The fruits are edible (Indigenous)
15	*Flueggea virosa* Roxb.ex willd	Phyllanthaceae	The bark is boiled to treat intestinal worms in herbivores(Exotic)
16	*Lecanodiscus fraxinifolius* Juss.	Sapindaceae	The fruits are edible and important for medicinal purposes(Indigenous)
17	*Commiphora edulis* Heath, A. & Heath, R.	Burseraceae	The bark of the tree is soaked to treat malaria infections(Exotic)
18	*Turraea wakefieldii* oliv.	Meliaceae	Leaves can produce synthetic insecticides used to control crop pests(Indigenous)
19	*Ochna thomasiana* Engl. & Gilg	Ochnaceae	It is an ornamental plant(Indigenous)
20	*Trichillia emetica* Vahl.	Meliaceae	The bark is soaked for intestinal ailments(Indigenous)
21	*Bourreria nemoralis* (Gürke) M. Thulin	Boraginaceae	Provide building poles and its roots can treat stomach aches(Indigenous)
22	*Bombax rhodgnophalon*	Malvaceae	Its flowers are edible and is a medicinal plant(Indigenous)

In transect 2, the results showed that (11) mature tree species were recorded. *Azadirachta indica* (exotic tree) was the most abundant with (40) individuals which also related to the highest number of seedlings(213), followed by *Trichilia emetica* (11) with slightly high number of seedlings(36), *Pithecelobium dulce had* (8) mature species and the seedlings were almost the same in number(9). *Delonyx regia* with (4) mature species had the same number of seedlings(5) as well as *Leucana leucocephala which had the same mature tree species and seedlings* (2), *Ziziphus mauritiana had low number of mature tree species* (3) but with high number in seedlings(12). Again, *Ochna thomasiana had low count of seedlings(1)and* (3) mature tree species, *Adansonia digitata and Sterculia appendiculata had* (2) mature trees and (1) respectively but had no seedlings (Fig. 2).

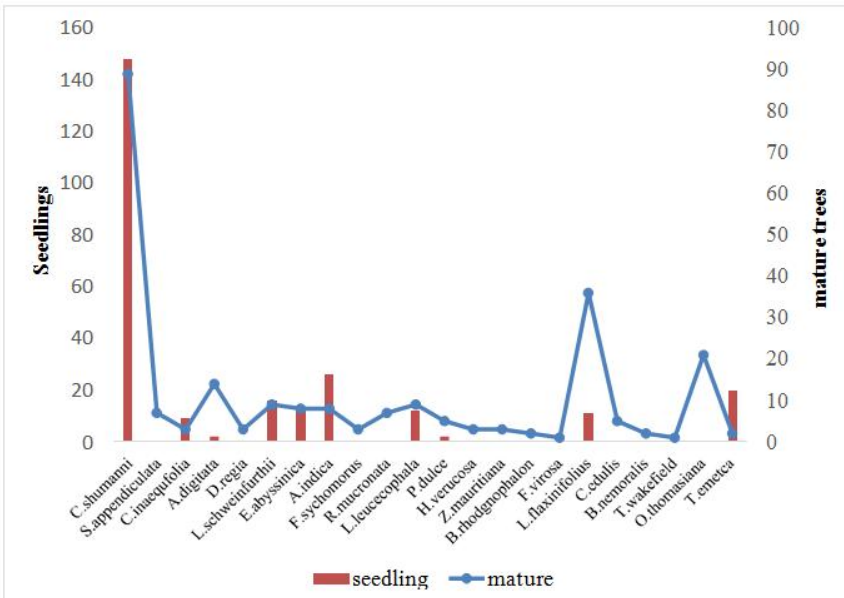

Fig. 1. Comparison between mature tree species and the seedlings number in Transect

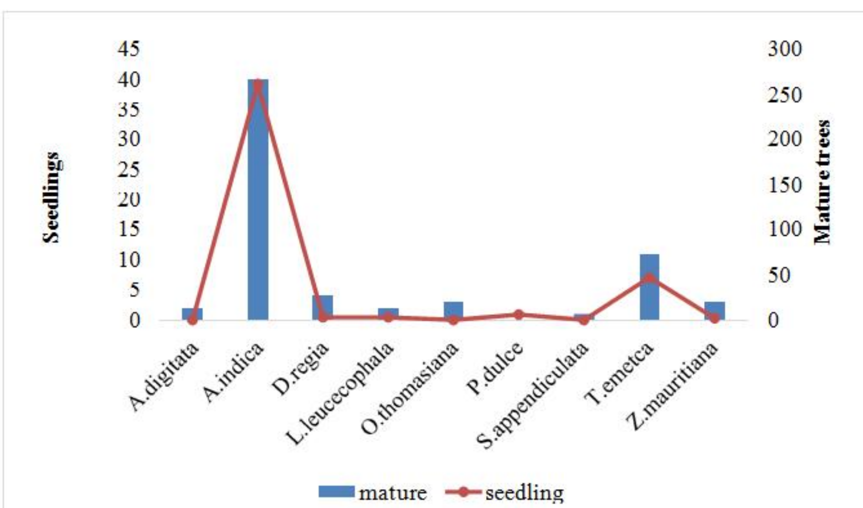

Fig. 2. Mature tree species and the seedlings number in Transect 2

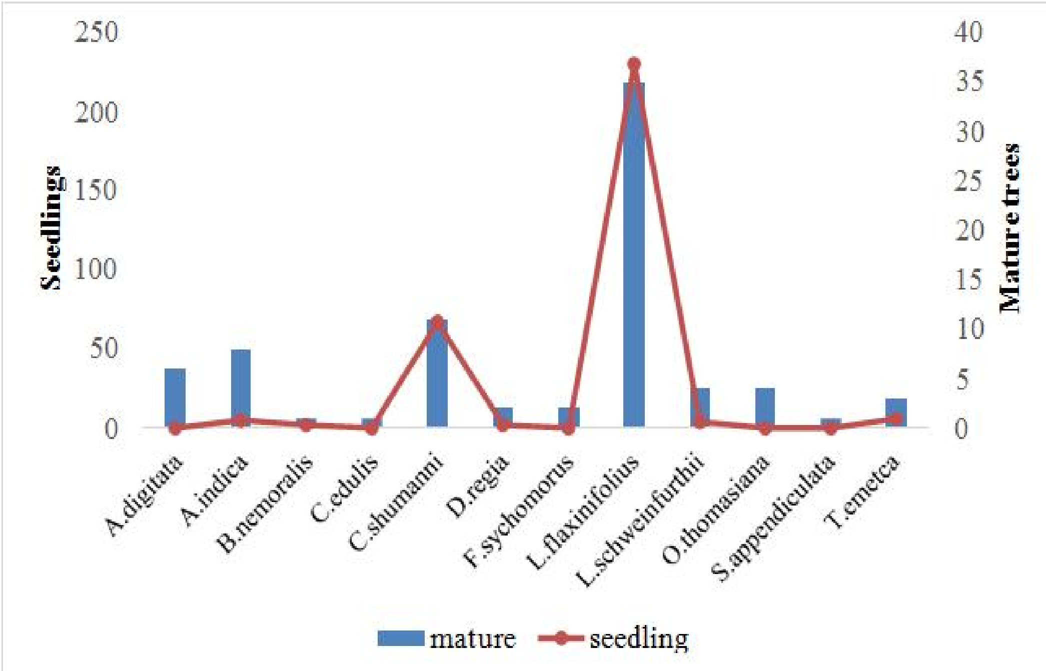

Fig. 3. Mature tree species and the seedlings number in transect 3

The results indicated that in transect 3, only 12 tree species were identified (Fig. 3). The most abundant tree species were *Lecaniodiscus flaxinifolius* with (35) individuals which also possessed the highest number of seedlings(144), followed by *Trichilia emetica* with (24) mature trees but with lower number of seedlings(2), *Cynometra schumanii had (* 9) mature individuals which also translated to the same number of seedlings(9). *Azadirachta indica* with (6) individuals had almost the same number of seedlings (7) whereas *Sterculia appendiculata had* (8), mature trees which also translated to (14) seedlings, *Delonyx regia* with (8) mature trees had(13) seedlings as shown in (Fig. 3).

Reduction of tree species count was observed in the transects. T1 had the highest number of tree species (22) followed by T2 (9) and lastly T3 had least tree species (12).

Correlation of mature tree species and seedlings in transect 1 gave a coefficient determination of R^2 =0.903 which is a strong positive correlation in the composition of seedlings and abundance of mature tree species (Fig. 4.)

Correlation of mature tree species and seedlings. In transect 2 gave a Coefficient of determination of R^2 =0.941 indicating a strong positive correlation in the composition of seedlings and abundance of mature tree species (Fig. 5).

Correlation of mature tree species and seedlings in transect 3 gave a Coefficient of determination of R2= 0.941. this is a strong positive correlation (Fig. 6).

Shannon weiner Diversity index Results for mature tree species

Shannon index H=∑-(Pi*InPi) I=1

Where;

H= shannon weiner index

Pi= Fraction of entire population made up of species i

S= Number of species encountered

∑= Sum of species 1 to species S H= 1.96

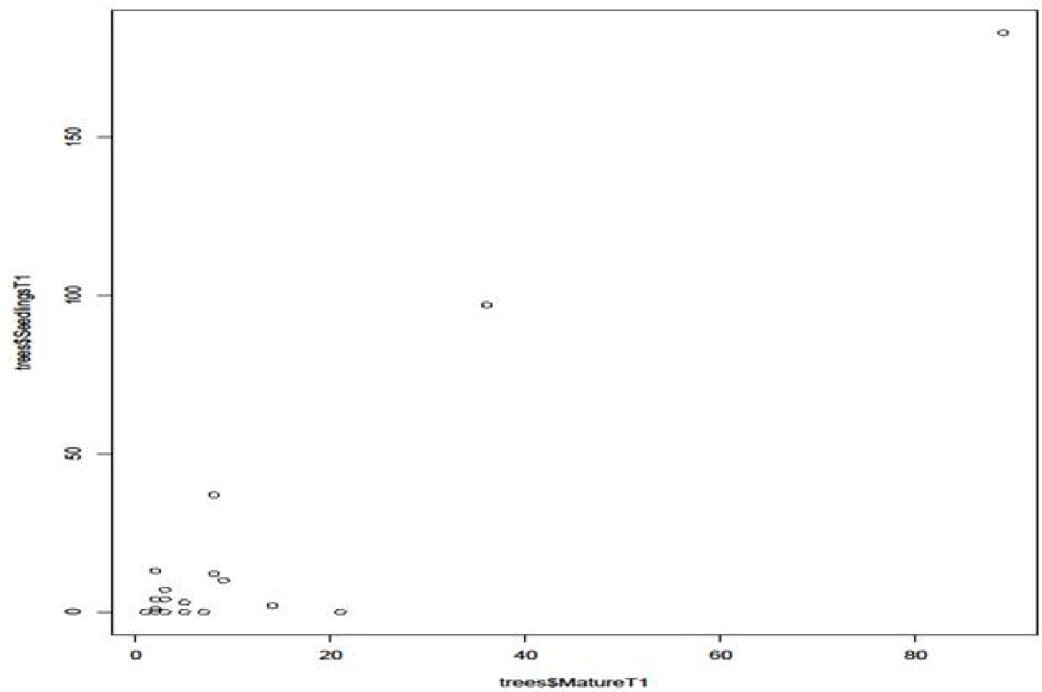

Fig. 4. Correlation of mature trees and seedlings in transect 1

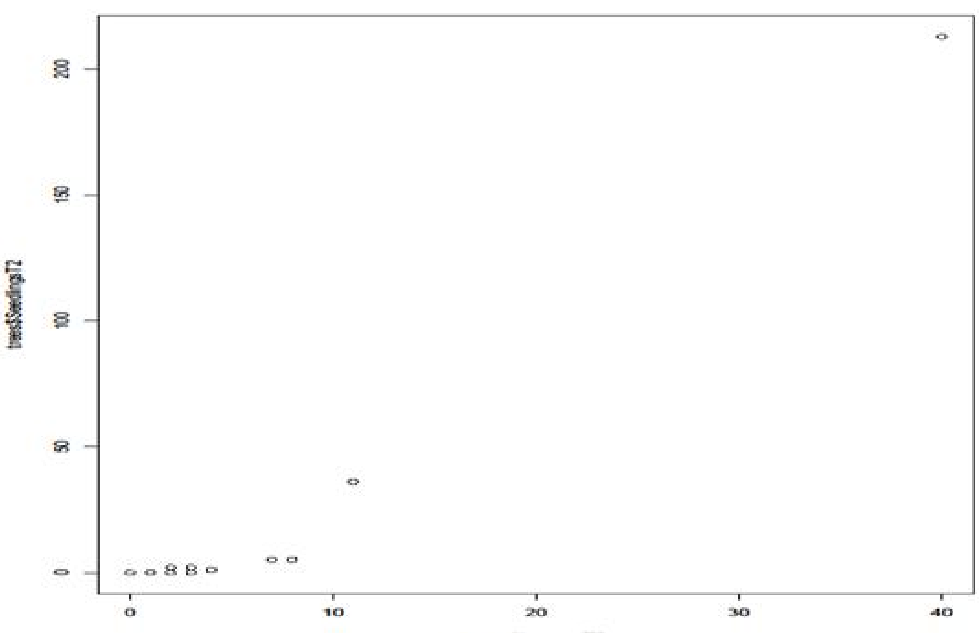

Fig. 5. Correlation of mature trees and seedlings in transect 2

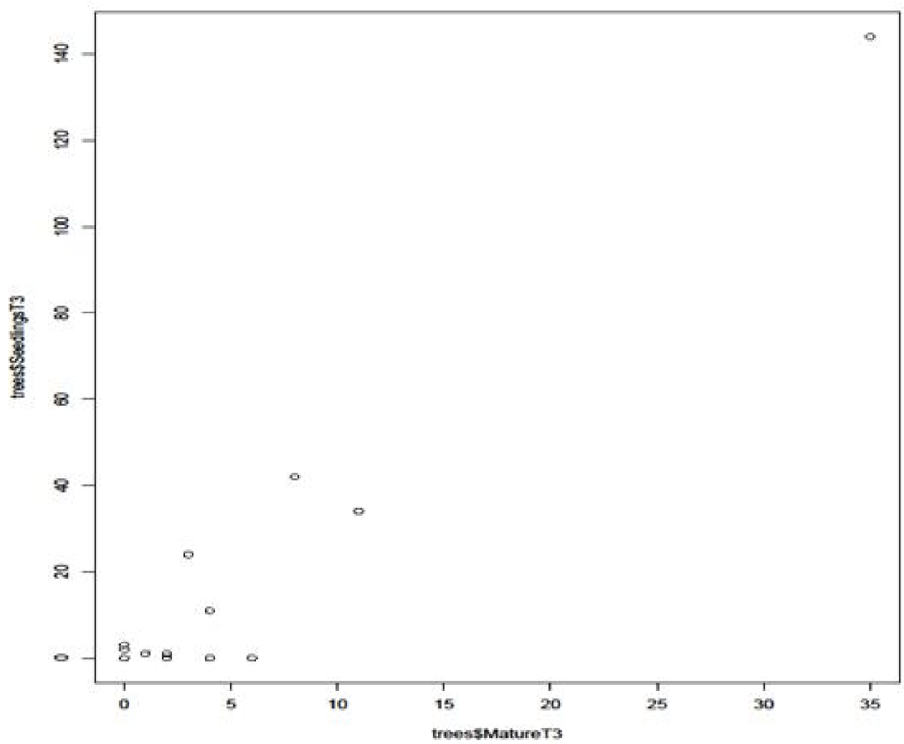

Fig. 6. Correlation of seedlings and abundance of mature tree species in transect 3

4. DISCUSSION

Mnarani ruins forest had a total 22 tree species idenfied upto species level, with 15 indigenous species and 7exotic tree species(*Azadirachta* indica, *Pithecellobium dulce, Leucaena leucocephala, Delonyx regia*). This is an indicator that the indegenous tree species are more dominant in the forest than the exotic. Although these number of tree species in Mnarani forest is lower compared to 50 indigenous tree species reported in Gede ruins forest which is also a coral rag forest [14]. Further some tree species found at the site were similar to those of Gede ruins forest such as *Sterculia appendiculata*, *Trichilia emetica*,*Ochna thomasiana, Adansonia digitata, Lecanodiscus fraxinifolius, Combretum schumanii* and *Cynometra webberi*. All species from Mnarani are useful amongst which are multipurpose eleven with (11) medicinal, six (6) fruit trees three (3) construction, four (3) ornamental, one (1) fodder, one (1) pesticidal and one (1) for prevention of soil erosion.

Thetransect along the ocean had the highest number of mature tree species (22) compared to transect along the human settlement (9) and (12) along the forest path probably because of less accessible from human unlike the two transects which were exposed to anthropogenic fact. The results are in line with those of [15]. All species were found on the transect along the ocean with *Combretum schumanii* the most abundant in both mature trees (89) and seedlings (189), followed by *Lecaniodiscus fraxinifolius*, *Ochna thomasiana* and *Adansonia digitata* were also abundant. All the above abundant species except Adansonia digitata which is a large seeded tree also had abundant seedlings. The decline in large frugivores could be the cause of low capability of seed dispersal hence less seedlings [16]. Although *Azaiarchata indica* had abundant seedlings along the ocean, this did not translate to abundant mature trees, this could be a result of delayed invasion due to genetic changes that increase the invasivisity potential as many invasive species do not invade immediately [17]. This transect also had rare species which were not found in the transect along to the settlement and near the path. The species restricted to the transect along the ocean were include *Bourreria nemoralis, Flueggia* *virosa*, *Turraea wakefieldii, Erythrina abyssinica*, *Ochna thomasiana,Bombax rhodgnophalon, Ficus sychomorus* and *Rhizophora mucronata.*

The transect(2) along the settlement had the least species (9) compared to the transect along the ocean (Fig. 2). There was a likelihood of anthropogenic factors affecting the species richness closest to the settlement either by over-harvesting or through habitat change. Morever, most likely seedling regeneration of most species were affected [18]. The mature trees and seedlings of *Azadirachta indica* were the most dominant species in the transect closest to settlement with 40 - cuttings,trails mature trees and 213 seedlings. This could be a reason of *Azadirachta* being an invasive species [19], hence a possibility of it thriving under disturbed conditions which most indigenous species cannot. *Combretum schumanii* was successful at seedling stage, but no mature trees as in the case [20]. This suggested that trees in general have a very low probability of surviving from a seed to a reproductive adult, which is estimated to be from 1 in 10 000 to 1 in 1 000 000 were in this transect.

The third transect along the forest path had the fewer tree species (12) and out of which three (3) were exotic. *Lecaniodiscus fraxinifolius* was the most common with 35 mature tree and 144 seedlings (Fig. 3). This was followed by *Trichilia emetica*. Seedling regeneration of the two species was also highest, irrespective of the location which seems to be more disturbed this is possible according to [21] MacArthur 1972) who suggested that more species-rich communities are thought to utilize resources more completely, making it more difficult for an invading species to establish and successfully compete. In general, *Trichilia emetica, Azadirachta indica, Delonyx regia,Lanea schweinfurthii and Adansonia digitata* were the most common species found in all transects while the unique tree species included: *Erythrina abbysinica,Turraea wakefieldii,Ochna. thomasiana,Bombax rhodgnophalon,Ficus sychomorus* and *Rhizophora mucronata* which were restricted to transect 1, along the ocean. Most of the tree species found in Mnarani ruins forest are unique to the coral rag forest with an exception of *Combretum schumanii* and *Cynometra* webberi which are found in Arabuko Sokoke forest Strong positive correlation of 0.903 in along the ocean (T1) and 0.941 along the settlement (T2) and along the forest path (T3) was also noted. As the abundance of mature tree species increases, the number of seedlings increases which is a good sign of forest recruitment. The abundant mature tree species had high number of seedlings count and have the possibility of dominating the forest. Finally, using the Shannon Wiener diversity index H= 1.964 hence, there is high tree species diversity at Mnarani Ruins forest and evenness equals to 0.635.This was an indicator of high tree diversity within the forest. According to [22] the larger the value of 'H' the greater the diversity and vice versa.

5. CONCLUSION

The study showed that Mnarani ruins forest had many indigenous tree species diversity than exotic tree species, although lower in numbers. All the identified tree species were useful and hence the need of conservation. The loss of species especially in the accessible sites was evident. The recruitment of trees was variable. It was also evident that human encroachment strongly reduced species richness indicating that man is the greatest threat to the biodiversity of Mnarani forest.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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