Chapter 13
Impact of Invasive Nypa Palm (*Nypa Fruticans*) on Mangroves in Coastal Areas of the Niger Delta Region, Nigeria

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Abstract Invasive nypa palms (*Nypa fruticans*) are a major threat to mangroves and coastal systems in the Niger Delta region in Nigeria, apart from oil and gas exploration. The palms were first introduced as foreign species to curb coastal erosion over a century ago (i.e. 1906). They later became invasive and started multiplying in the last 30 years. The palms have acclimatized to the coastal environment by developing superior root system, which they use to tap available nutrients. They also have tough and buoyant seeds, which aid in their wide dispersal. These qualities of the palms had made them to have an edge over the mangroves. Oil and gas exploration, which is responsible for numerous oil spillages, is a major cause of mangrove decimation. The establishment of open waste disposal sites in coastal areas have also contributed to the changes in soil and water qualities, leading to further decline in mangroves, with a resultant increase in invasive nypa palms. The palms change the pedology, hydrology and landscape architecture of the coastal environment once they are established. Therefore, a threat to the mangroves is a threat to the entire coastal system, which benefits from the ecosystem services provided by the mangroves. Mangroves may disappear completely from the Niger Delta in the next 50 years if the encroachment of the palms continue unabated. However, this problem can be resolved by the removal of the palms through mechanical, physical or chemical means. Soils on which the palms grow can be excavated to remove the allelopathic properties, after which the palm soil should be replaced with mangrove soil. To ensure smooth re-colonization of the coast, mangroves propagules with good genetic quality should be selected, nurtured and transplanted from the nursery to the coastal areas. The mangrove propagules should be monitored and protected from further invasion by nypa palm after planting.

Keywords Niger Delta · Nypa palm · Invasive species · Hydrocarbon pollution · Mangrove · Exploration · Seismic activities · Oil spillages · Restoration

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13.1 Introduction

Invasive species are plants and animals that are intentionally (aquaculture, agriculture, recreation and ornamental purposes) or unintentionally (humans, airplanes, cars, shirts, ships etc.) introduced into foreign lands (Davis 2009), and become physically and genetically more superior than their host species when they arrive. In addition, invasive species hitch hike to foreign lands on vehicles or vessels (Crosby 1986; Hodkinson and Thompson 1997). Similarly, species are also introduced to foreign land through international trades and travels by humans who carry crops to Africa, Asia, Europe, Australia and America. The foreign species compete with the host species for resource and space, which leads to serious impacts on host species ability to survive. The impact can be direct through predation, competition, parasitism and disease, or indirect through resource competition, trophic cascade, habitat modification (Wootten 1994), ecosystem impact through habitat structure, disturbance regime, nutrient cycling and hybridization. Some of the invasive species are ecosystem engineers, because they change the fundamental aspect of the physical and chemical environment in their new location (Jones et al. 1997). Invasive species also exhibit propagule pressure by producing large pool of source population, which overwhelm the native species. Other impacts of invasive species in coastal areas include: population and community impacts, morphological impacts and genetic and evolutionary impacts. Many studies had come up with some theories concerning the actions of invasive species. Two of these theories are biotic resistance hypothesis and energy release hypothesis. Biotic resistance hypothesis postulates that community diversity affects invasion success (Elton 1958). This means species rich communities are more resistant to invasion. Thus if species are packed into a community they effectively utilize the resources, and prevent the creation of empty niches, which discourage invasive species (Elton 1958). This is because an empty niche will lead to competition for unused and abundant resources. Likewise, consumption by natives reduces invasion success. This is because invading species meet their waterloo in foreign lands when native species fight back. Energy release hypothesis, on the other hand, postulates that invasive species spread rapidly due to the absence of co-evolved natural enemies in the introduced range (Elton 1958; Keane and Crawley 2002). It also means that when there is an abundance of enemies in a native range, they prevent the native species from succeeding whereas the invasive species prospers because by leaving their home base they leave behind most of their natural enemies. However, studies had shown that most introductions fail, for example, starlings, a small to medium sized passerine birds in the family of Sturnidae, failed at its initial introduction.

Nevertheless, nypa palm (*Nypa fruticans*) is one of those species that didn't fail, but rather became very successful at its initial introduction. It is now a major invasive species and a threat to coastal areas in the Niger Delta. This is because the palms have suppressed the growth of mangroves and other coastal species with their explosive population growth. They are able to over crowd the coastal areas because of the high production and effective distribution of their seeds around major creeks and rivers in the region. They grow outwardly from the center of the forest towards the river, constricting the waterways. The palms prevent the growth of other coastal species by occupying every unoccupied inch of land along the coast. However, mangrove growth is different from nypa palm growth because mangrove supports food chains, and food webs and helps in the proliferation of other species in the coastal environment (e.g. epiphytes). For instance, mangrove forests serve as spawning ground for various aquatic organisms, whereas the palms destabilize ecosystem function by pushing away many organisms (e.g. fishes), and making it difficult for local fishermen to have good catch whenever they go for fishing. This results to them sailing further into the Atlantic Ocean to get more catches.

The nypa palms (*Nypa fruticans*) in the Niger Delta region originated from Asia (Jones 1995), but were intentionally introduced into the Niger Delta to fight coastal erosion in 1906 (Keay et al. 1964). The first point of contact of the palms was Calabar, a town in the Niger Delta, from where they spread further south to other coastal towns along the Atlantic Ocean, aided by human activities and tidal currents. One major cause of their spread in the coastal areas is oil and gas exploration activities, which involved forest clearing to create room for seismic work, and deforestation, which changed the landscape of mangrove forest from undisturbed to disturbed state, after the entry of the exploration parties (Fig. 13.1). These actions lead to the proliferation of several alien species such as grasses. Similarly, the arrival of exploration teams led to the construction of boot camps and residential quarters to accommodate field workers, which further attracted a lot of human presence around the forest leading to gradual urbanization of the coastal areas. The creeks and rivers around Okrika, a host town to a major refinery in the Niger Delta, have a lot of oil facilities (e.g. pipelines, well heads, oil jetties etc), which helped to change the configuration of the forest by making it possible for the nypa palms to invade and colonize most areas around the coast (Fig. 13.2). In contrast, Buguma another town has no major oil infrastructure, but few well heads with sub-surface pipelines with limited nypa palm presence (Fig. 13.2). Nothwithstanding, during one of our field trips a nypa palm seedling, about 1 m tall was found growing within the mangrove forest by the sea shore, which most likely was brought in by tidal current. The seedling was uprooted and destroyed, but whether that singular action will prevent further entry and growth of the palms still remains to be seen.

The palms had adapted to the environment and had become a major threat to the native mangroves. The palms are found along the rivers of most of the coastal towns in the Niger Delta region such as New Calabar, Nun, Imo, Saint Barbara, Saint Bartholomew, Orashi, Bonny, Opobo, and Andoni Rivers. They occur in mixed or pure species stands (Wang et al. 2016) at the fringes of the sea where they block water channels and navigational routes. They also clog up drainages, thereby causing the stagnation of fast moving streams. The palms do not only affect coastal environments, they also affect transportation along the river by causing boat accidents, which results in injuries and deaths (Fig. 13.3) because of poor visibility, caused by the blocking of view of boat drivers when they meander through the creeks.

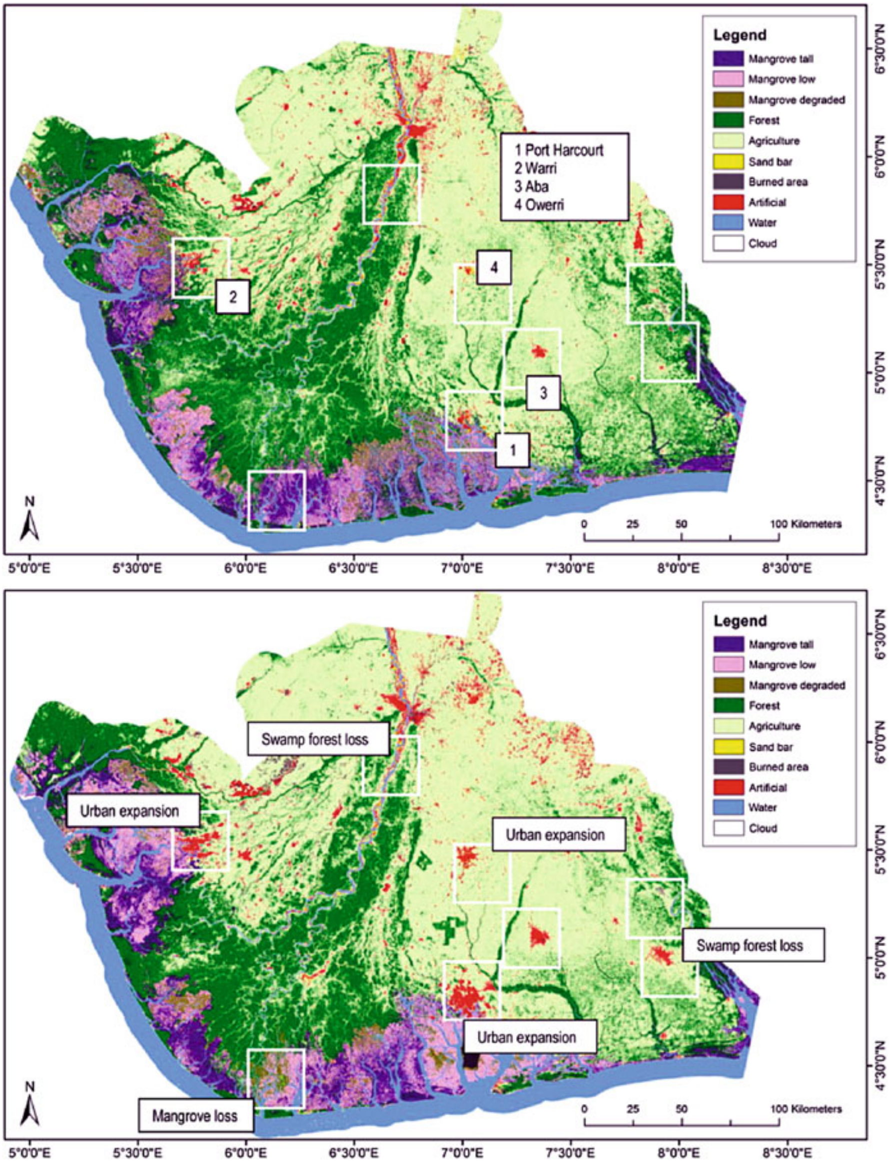

Fig. 13.1 Mangrove forest loss in the Niger River Delta, Nigeria is as a result of urban expansion and other anthropogenic activities (e.g. oil and gas exploration, deforestation, invasive species etc). Mangrove loss is also triggered by agricultural activities leading to the formation of sand bars (Kuenzer et al. 2014), and the reduction of wet mud (Wang et al. 2016)

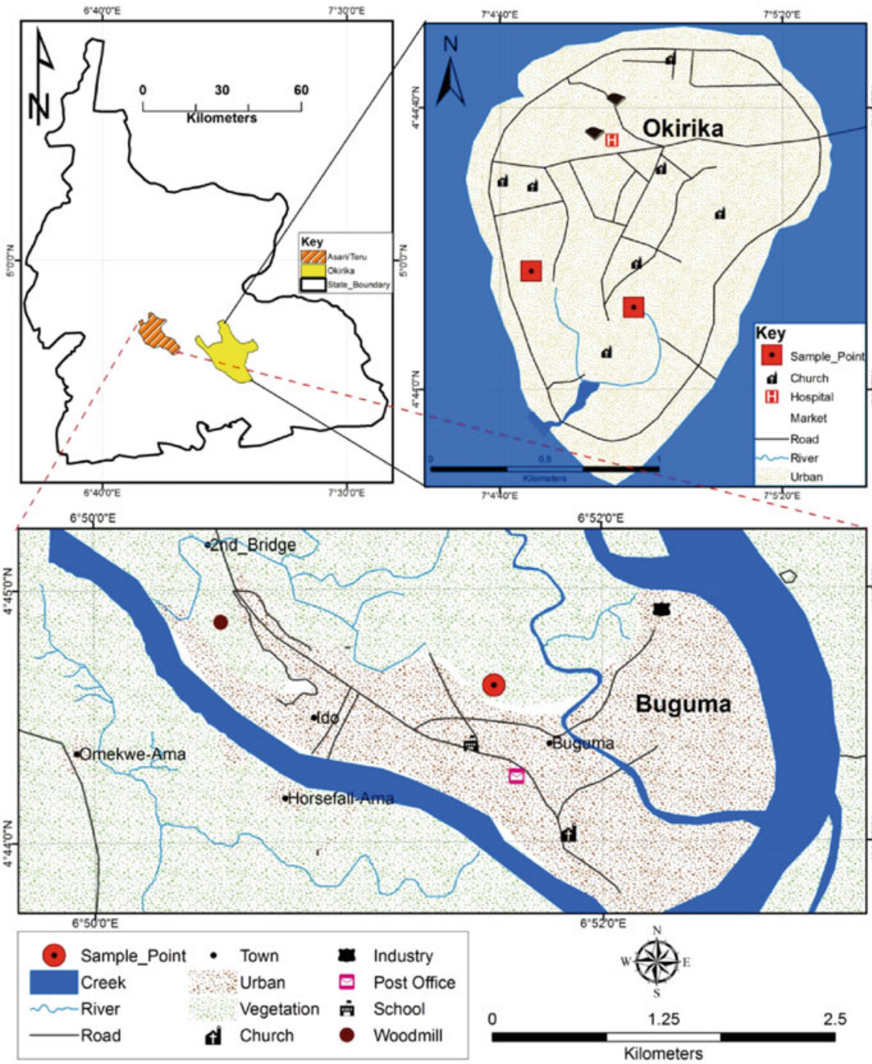

Fig. 13.2 Two study areas in the Niger Delta that had already been invaded by nypa palms (*Nypa fruticans*). The rivers and creeks around Okrika had been over run by the palms, due to years of oil and gas exploration activities which caused crude oil spillages while nypa palm invasion in Buguma had been low because of low oiling activities

Fig. 13.3 Nypa palms invade a small mangrove forests and also constricts a navigational route for sea travelers at Eagle Island, Niger Delta Nigeria. Some sections of the forest had already been dredged on the left side of the picture for the purpose of sand mining and the establishment of an industrial complex

13.2 Factors Influencing Nypa Palm Expansion in the Niger Delta Region

13.2.1 Anthropogenic Factors

Anthropogenic activities contribute greatly to the invasion and spread of nypa palms in the Niger Delta. Oil and gas exploration and exploitation activities which began in 1956 through the striking of the first oil well in Oloibiri town, Niger Delta was particularly a major factor that opened up the mangrove forest to invasion by palms (Figs. 13.4 and 13.5). Exploration for crude oil is one of the first activities that led to the deforestation of vast amount of virgin mangrove forest, aimed at creating a right of way (ROW) passage for seismic lines, laying of pipelines and setting up of base camps (Fig. 13.5). The paths created within the forest do not grow several years after their establishment (Ohimain et al. 2008), but become passages for humans and animals, which use the route created to penetrate deeper into the forest to plunder its resources. Local people take advantage of the cleared area to hunt for animals and set up crop farms while oil workers go into the forest with heavy machinery

Fig. 13.4 Google image of a major crude oil pipeline linking the Port Harcourt refinery and the sea jetty at Okrika, where crude oil is evacuated and transported abroad. Some years ago (i.e. in the year 2010) this location was exclusively a mangrove forest, but of recent most of the mangrove stands had been taken over by the palms. This is because of constant hydrocarbon pollution from broken pipes, and deforestation aimed at clearing the path along pipeline routes, which results in the death of mangrove trees. (Credit: Google Earth)

that disfigures the swamp and introduce foreign species that are picked up along the way.

Hydrocarbon pollution is an outcome of exploration activities, and it occurs during the drilling of oil wells and the transportation of crude oil through pipelines along sea and land routes. Oil spillages occur during pre-exploration, exploration and post exploration stages. The spilled oil changes soil and water qualities and affects the growth of coastal organisms. Reduction in soil quality impedes the growth of native plants, and accelerates the growth of foreign species. Studies had shown that nypa palm seedlings grow better than mangrove seedlings when both are planted in mangrove soil. Similarly, nypa palm seedlings survive longer than mangrove seedlings when both are planted in polluted mangrove soil (Numbere and Camilo 2016a). Contamination of the water body also leads to the death of aquatic organisms and the destruction of the food chain, which depends on the coastal life for survival.

Fig. 13.5 Dredging activity to create pipeline route through the mangrove forest in Bakana town, Niger Delta, Nigeria. (Credit: A.O. Numbere)

Fig. 13.6 Encroachment of nypa palms into mangrove forest (*Rhizophora mangle*) along a waterway leading to Bakana Town, Niger Delta, Nigeria. Invasion of the palms is facilitated by anthropogenic activities such as oil and gas exploration, dredging, sand mining, and urbanization. (Credit: A.O. Numbere)

Fig. 13.7 Building of houses right in the mangrove swamp destroys the native mangrove species and open the way for the invasion of the coastal area by alien species such as nypa palms and a variety of grass species. This location was formerly exclusively occupied by mangrove species, but now only a little patch of mangrove stand still remains at the background of the picture. One of the contributing factors is the use of the location as a refuse dump site, which changes the soil to dirty brown that is mixed with greenish algae (e.g. spirogyra). (Credit: A.O. Numbere)

Dredging activities destroys the native mangrove stands and creates an opening for nypa palm seeds to enter and multiply. In the same vein, the contamination of the soil as a result of oil and gas exploration activities also changes the soil quality leading to the death of the mangroves and the proliferation of the palms as recorded in many sites across the Niger Delta (Fig. 13.6).

Urbanization is a key anthropogenic factor that drives the growth of invasive palms. The palms have more affinity for disturbed than undisturbed soil. Urbanization in this context is the replacment of mangrove forest with urban centres, which promotes the spread of palms by changing the soil quality (Fig. 13.7). This involves the destruction of mangrove forest stands and the building of houses right in the mangrove swamp. This action creates the way for the invasion of other alien species. Conversion of wetlands into place of human habitation leads to the generation of human waste, which further reduces the quality of the environment. A disturbed forest is a fertile ground for the proliferation of the palms. The practice of aquaculture in wetland also degrade native mangrove, and encourage the introduction of foreign species. Mangrove forest had been degraded from high density to low density mangrove for the last 20 years in the Niger Delta (Wang et al. 2016; Kuenzer et al. 2014).

13.2.2 Pedology/Changes in Soil Condition

Mangroves are habitat specialist, and grow only in coastal areas (Nagelkerken et al. 2008). Therefore, a change in soil condition from swampy to sandy soil is detrimental to their survival. Mangroves grow better when they are in their native soil, which is swampier and richer in nutrients than the nypa palm soil. This is in agreement with a previous study which indicates that soil effect had more influence on invasion success than species richness (Stohlgren et al. 1999). The typical mangrove soil is coffee brown in color, slightly muddy and has a pungent ammonia-like smell, which breathes life into the mangrove forest and accelerates the growth of organisms. On the other hand, the palms grow on a variety of soils such as mangrove soil, muddy soil, sandy soil and algae-infested soils. Studies done using soils from different locations show that growth in height of nypa palm seedlings was mainly influenced by soils derived from highly polluted forest than soils derived from lowly polluted forest. Another study also indicates that nypa palms grow better than mangroves in mixed forests (i.e. a combination of mangrove and nypa palm trees growing together) than in pure forest (Wang et al. 2016). This is one of the reasons why the palms out-compete the mangroves when they infiltrate mangrove forest (CEDA 1997). Nypa palm has better growth in mangrove soil than in its own soil. Studies had shown that the growth of nypa palm seedlings in mangroves soils is as a result of the utilization by the palms of the un-used nutrients that are locked within the mangrove soil. One of the conclusions of this study is that nypa palm performed better in mangrove soil and worse in its own soil, in terms of growth in height and production of leaves. Similarly, nypa palm produced more seeds than mangroves in mixed forest. This gives the palms advantage over mangroves because with time the seeds of the palms will germinate and colonize the entire area. This situation is a recurring factor in many locations in the Niger Delta.

During several field trips to many locations it was observed that mangroves growing in core nypa palm forest don't have better growth. This led to the conduction of a pilot study to test the growth performance of mangrove and nypa palm seeds in mangrove and nypa palm soils. We collected soils from both mangrove and nypa palm forest and placed them in a swamp box (Numbere and Camilo 2017b). Twenty five (25) seeds of mangroves (*R. racemosa*) without blemish were planted in each soil, and left under semi-natural conditions for seven months (i.e. March—October). The plants were watered daily with river water collected in-situ, and left in the open, under the elements of the weather. The result was stunning, and provided some answers to why the palms are always performing better than the mangroves, and why the palms had continuously colonized several mangroves forest in the Niger Delta in the last few years. The result showed a robust growth of mangrove seeds planted in mangrove soil and a stunted growth of mangrove seeds planted in nypa palm soil (Fig. 13.8). This experimental growth in a nursery is what has been replicated in the natural environment, which had made the palms a more superior competitor than the mangroves, leading to the domination and eventual elimination

Fig. 13.8 Swamp box experiment showing two partitions of: (**a**), mangrove soil and (**b**) nypa palm soil. Twenty five mangrove seeds were planted in each section. They were watered daily with river water, and monitored for seven months, March—October, 2017. The result indicates that mangrove seeds in mangrove soil had robust growth while mangrove seeds in Nypa palm soil had retarded growth. Result of this study is a classical example of what happens in the natural environment where Nypa palms are quickly colonizing the coastal areas at the detriment of the native mangrove species. (Credit: A.O. Numbere)

of mangroves in several locations. More studies are ongoing with more replications to reinforce the hypothesis that invasion of nypa palms in mangrove forest has a lot to do with changes in soil quality.

13.2.3 Hydrology

Dredging and sand filling activities change the hydrology and affect mangroves and other coastal species (Fig. 13.9) (Ohimain 2004). Sand filling brings in excess sediments along with foreign species into wet land region, which smothers and overwhelm native species. Sandy soil that is pumped from the bottom of the sea unto the shore comes along with foreign species, which invade the coastal areas. Some aquatic organisms such as mangroves do not grow on sandy soil. Moreover, the change in creek size influences tidal flow rate, and affects stream physico-chemistry. Similarly, expansion of the coast through channel canalization (Fig. 13.10) leads to the inadvertent entry of invasive species while reduction in stream size increases tidal pressure with ripple effect on stream chemistry (e.g. salinity) and species population dynamics (e.g. increased competition). Changes in the salinity level of the stream through dredging activities affect species composition and distribution.

Fig. 13.9 Google Earth image of Buguma, a town in the Niger Delta, Nigeria that was sand filled in 1984 for the purpose of building houses to accommodate increasing population of the local residents. Till date the sand filled area (white patch) has not supported the growth of any mangrove forest, rather different foreign species such grasses had dominated the area covered by the sandy soil. Similarly, some tributaries connected to the river had been blocked by the sand. Some seeds of nypa palms were recently detected on the shores of the river, which indicates that in a matter of some years the remnants of the mangrove forest seen in the picture would be endangered and may go into extinction in the next 20 years if nothing is done. (Credit: Google Earth)

Mangroves are generally halophytic, but the distribution of individual species depends on the salinity level of the location. For instance, *Rhizophora* species are less halophylic whereas *Avicennia germinans* are more halophylic (Lugo 1980), which affects their distribution. During the transition period after dredging, the area is usually invaded by opportunistic foreign species as the native species migrate to a more habitable environment.

Dredging of the coastal areas to lay pipelines disturb the soil structure and composition and destabilize the growth of mangroves and other coastal species. Nypa palms invade areas made bare by deforestation. The dredging activity changes the soil and water quality and prevents the mangroves from growing, leading to their gradual death and loss from the environment (Fig. 13.10). In the same vein, urbanization and improper waste disposal are leading to the disappearance of many mangrove forest along the coastal areas (Fig. 13.11).

Channel reduction changes stream chemistry and size, and lead to the formation of "mangrove islands", which are a preparatory stage for the complete elimination of

Fig. 13.10 Mangrove swamp dredged to lay pipelines that connect an oil tank at the far end of the picture. Years of disturbance of this coastal location at Eagle Island, Niger Delta, Nigeria through sand mining, dredging and improper waste disposal had exposed the mangrove forest to invasion by nypa palms and other alien species as seen on the left side of the picture. (Credit: A.O. Numbere)

small mangrove communities (Fig. 13.12). Stream reduction also constricts space for the free movement of species, and triggers competition amongst aquatic organisms. For instance, some parts of Eagle Island in the Niger Delta, previously had a combination of red (*R. racemosa*) and white (*A. germinans*) mangroves, but now have only white mangroves because of changes in hydro-chemistry as a result of sand dredging and sand filling that took place in the area (Fig. 13.12a). It was observed that the white mangroves performed better in sandy and disturbed soils than the red mangroves. Red mangroves (Rhizophora) are the most dominant coastal species in core undisturbed mangrove soils. Therefore, during dredging and contamination of the coast they become the first victims of long term soil degradation.

The second location is Eagle Island (Fig. 13.12b), which has most of its mangrove stands destroyed. This is because of the toxic effect of sawdust that was dumped into the river by a wood mill industry located nearby. But this physico-chemical change does not affect the palms, which continued to grow as shown in the background in Fig. 13.12b. The palms generally thrive in polluted soil, thus they are not affected by the organic waste materials that are dumped into the river.

Fig. 13.11 A patch of mangrove stand (*Rhizophora mangle*) is boxed into a corner between some urban settlements and invasive species. Already the mangrove stand on the left hand side had withered. Between both stands is a heap of refuse dumped by inhabitants of the adjoining apartments, which had changed the color of the river to green due to algal infestation. The proliferation of urban settlements around the coast had led to an increase in waste generation, which had contributed to the invasion of alien species. (Credit: A.O. Numbere)

13.2.4 Root Micro Structure

Nutrient absorption is carried out by the roots, and determines the rate at which the plant adapt to their environment. Microscopic study of the roots of red mangrove and nypa palm using electron microscope in the laboratory of the Department of Animal and Environmental Biology, University of Port Harcourt, Nigeria, indicates that the roots of palms are structured to carry out better nutrient absorption than roots of mangroves. The root of the palm is light in texture, hollow and straw-like while the root of red mangrove is thick and tightly packed (Fig. 13.13). The root of nypa palm is completely embedded in the soil and grows deep down the soil profile while mangrove roots are mostly adventitious with many parts growing outside the soil in other to carry out aerobic respiration. The palm roots go deep down the soil profile to tap unused nutrients while some roots of mangroves grow at the surface layer. In addition, mangrove roots are woody and less permeable as compared to the roots of nypa palm that are tender and highly permeable.

Fig. 13.12 Changes in coastal hydrology impact (**a**) white mangroves (*Avicennia germinans*) through channel reduction via sand filling and (**b**) red mangroves (*Rhizophora racemosa*) through changes in river physico-chemistry as a result of pollution. Both factors affect the distribution of mangroves leading to the formation of "mangrove islands" and the intrusion of nypa palms as seen in the background in (**b**). Figure 13.12 (**a**) has white mangroves (*Avicennia germinans*) and no red mangroves around because of changes in salinity, while in Fig. 13.12 (**b**) the red mangroves (*Rhizophora racemosa*) are gradually being replaced by nypa palms. Similarly, (**b**) shows one of the few last stands of red mangrove (*R. racemosa*) trees being surrounded by nypa palm in this location in Eagle Island, Niger Delta, Nigeria. (Credit: A.O. Numbere)

Again, in another study mangrove roots were found to have more un-transported nutrient content as compared to nypa palm roots when 20 mangrove and 20 nypa palm root samples were dissected and analyzed for nutrient content in the laboratory. The result indicate that average total nutrient content was more in mangrove roots

Fig. 13.13 Root structure of (**a**) nypa palm and (**b**) mangrove. Nypa palm roots are light and fully embedded in soil while mangrove roots are thick and adventitious. (Credit: A.O. Numbere)

(123.9 ± 121.1 mg/kg) than in nypa palm roots (44.9 ± 40.7 mg/kg). The nutrient content is a combination of Nitrogen, Phosphorous, Potassium and Nitrate. Furthermore, the result of this study indicates that there was no significant difference ($P = 0.55$) in nutrient content between nypa palm and mangrove root. Nonetheless, the low amount of nutrient content in the roots of nypa palm could mean that there is a faster transmission of nutrients from the root to other parts of the plant as compared to the mangrove root. However, out of all the nutrient elements analyzed potassium (K) was the most dominant, and had higher concentration in mangrove root than in nypa palm root.

Fig. 13.14 Nypa palm seeds occur in groups of 20–30 seeds and are tough and have high buoyancy rate, which enables them to float to far distances around coastal areas of the Niger Delta, Nigeria

13.2.5 Seed Buoyancy

The exocarp of nypa palm seed acts like a floater (Fig. 13.14), and enables the seeds to remain afloat for long in the aquatic environment. The buoyancy of the seed makes it to travel thousands of kilometers in and around the coastal regions of the Niger Delta. As a result of this situation, one would hardly find a location around the riverine areas of the Niger Delta without the presence of nypa palm seeds. Another advantage of the seed structure is that it has tough outer covering, which prevents it from being soaked by water or permeated by pollutants such as crude oil. The toughness of the seed also prevents it from being consumed by crabs or other organisms around the mangrove forest, unlike the mangrove propagule that is soft, palatable and edible.

13.2.6 Landscape Changes

Human activities lead to the changes in landscape architecture in coastal areas, which facilitate the invasion of foreign species (Wang et al. 2016). The use of the coastal area as a waste disposal site had led to the complete displacement of mangroves in some locations such as the Eastern Bye Pass section of a prominent Creek in the Niger Delta called the “Ntawogba creek” (Fig. 13.15a). This location was formerly an exclusive mangrove forest. Many other places that were once occupied by mangroves are now completely invaded by the palms in mixed or pure forest stands. As mangroves disappear, the ecosystem services they render also disappear along with them such as fire wood, coastal protection, flood control,

Fig. 13.15 (**a**) A time-line of a former mangrove forest that was completely invaded by nypa palms in 2014; (**b**) The same location after it was sand filled in 2017 (i.e. Eastern-Bye Pass Creek, Niger Delta). Anthropogenic activity such as pollution, improper waste disposal, deforestation etc. contributed to the disappearance of the mangroves from this once vibrant mangrove forest. Since the palms had no economic value it was bulldozed by the local authority and sand filled. It is now a proposed site for constructing industrial and residential quarters. (Credit: A.O. Numbere)

shoreline protection etc. (Polidoro et al. 2010). The palms grow and block drainages (Fig. 13.15a), which are then cleared by dredging causing harm and disfigurement of the landscape. The dredging equipment used in clearing the forest further stresses the coastal environment by destroying benthic organisms. In some cases complete sand filling is done to reclaim the areas lost to nypa palm (Fig. 13.15). Observations had shown that the reclaimed locations are never returned to their original form, but are rather used as platform to construct developmental projects, such as housing complexes, industries, filling stations, offices, apartments, etc.

Invasive nypa palm obstructs waterways and affects navigational activities (Fig. 13.16). The palms constrict the width of the river channels as they grow and expand (Fig. 13.16), which cause maritime accidents of sea crafts. Constriction of the river channel affects the free movement and population structure of aquatic organisms. Canalization and sand dredging lead to sedimentation. This occurs when stands of palms act as barriers to water flow and filter to waste materials carried by river into coastal areas (Fig. 13.17). Accumulation of sand from other locations, especially from dredged soils changes the coastal area to sandy soil, and prevents the growth of mangroves and other aquatic organisms.

Fig. 13.16 A former mangrove forest, over ran by palms in Asarama community in the Niger Delta Nigeria. The pattern of growth of the palm is to stifle other plants around it and to block the water channels thus, preventing the free flow of oxygenated water. Non-flowing water around the forest traps waste, which decomposes to degrade the water quality. This increases the effect of pollutants, which are inimical to the health of the mangroves and the coasts in general. (Credit: A.O. Numbere)

Fig. 13.17 Accumulation of waste materials (log, dirt, branches etc) trapped at the base of nypa palm (*Nypa fruticans*) prevents the free flow of materials in the creek at Okrika, Niger Delta Nigeria. (Credit: A.O. Numbere)

13.3 Transformation of Coastal Areas from an Aquatic to a Terrestrial System

Mangroves were the dominant species along the coastal areas of the Niger Delta prior to the 1990's, but because of anthropogenic activities of oil and gas exploration, urbanization, deforestation and poor waste management, they had been displaced by nypa palms in many locations. The pattern of growth of the palms had made them to obstruct, and change the architecture of the stream channel leading to loss of several coastal species. Local authorities carry out sand filling and dredging of nypa palm invaded areas in other to reclaim the lost mangrove forest as shown in Fig. 13.18a, b. Similarly, private agencies mine sand from coastal areas, which they sell to construction companies for the purpose of building. In addition, the sand-filled locations are set aside for building projects. This situation can be described as a horizontal irreversible coastal change (Fig. 13.18a). This is because the area cannot be reverted to its original form after it has been converted from an aquatic to a terrestrial system. This process thus leads to the total elimination of all aquatic organisms in that coastal system including pelagic and benthic organisms, which is not good for the sustainability of the environment. This is because the coast helps to stabilize the environment by removing atmospheric carbon dioxide, and reducing the impact of global warming. The coast is also a haven for biodiversity such as aquatic and amphibious organisms. Therefore, the loss of the coast is dangerous for the whole environment. However, in this circumstance the best management strategy to adopt is a triangular reversible transformation

Fig. 13.18 Transformation of mangrove forest to (**a**) sand fill and (**b**) pure mangrove forest. Conversion of mangrove forest to sand fill area is a total loss to the coast. This pattern of change (Fig. 13.18) is often observed in the Niger Delta region whenever nypa palm forest is removed from a location. There is often no restorative effort aimed at bringing back the original mangrove forest, rather the area is reclaimed for other developmental projects or urbanization activities. But the best restorative effort is to bring back the area to its original state (Fig. 13.18b). This is to ensure that the mangrove forest does not slip into extinction in some years to come. (Credit: A.O. Numbere)

(Fig. 13.18b). This can be done after the area had been successfully colonized by the nypa palms in mixed or pure forest. To restore the site, the palms should be removed, and in their place mangrove seedlings planted. This can be done when the area is passing through its cycle of change from mangrove to mixed forest or from mixed forest to pure nypa palm forest. Physical, mechanical and chemical means can be used to eliminate the palms. Mangrove soil should then be brought in, and spread all over the area, after which young mangrove seeds are planted to ensure a rejuvenated growth of the mangroves.

13.4 Conditions That Favor Nypa Palm Invasion of Mangrove Forest in the Niger Delta

The entry of nypa palm into the Niger Delta was made possible by an invasion pathway (Carlton and Ruiz 2005) established by the presence of the Atlantic Ocean (Richardson et al. 2000), which facilitated travel from Asia to Nigeria, and made the intentional transfer of the seeds successful (Keay et al. 1964). On arrival to the new habitat the palms got adapted and became physiologically tolerant to the new environment. The life history of the palms matched the new environment. The palms also benefitted from untapped resources in the mangrove forest. These untapped resources are empty niches created by massive deforestation for oil and gas exploration and urbanization. These conditions thus created a disturbed environment, which encouraged a successful invasion, colonization and expansion. Incessant mangrove tree cuttings for fire wood also reduced the native mangrove

Fig. 13.19 A classic example of propagule pressure of nypa palm seeds in a mangrove forest. The palms are waiting to invade and displace the mangroves in a sand filled location in Asarama town, Niger Delta, Nigeria. On the left side of the picture are seeds of the white mangroves (*A. germinans*) hanging on a tree. It is not known if the mangrove seeds can withstand the difficult sandy environment to grow and populate the area, since the muddy mangrove soil on which they thrive is no longer available. (Credit: A.O. Numbere)

species diversity, and led to a geographical isolation that are characteristics of an invaded community. This is the reason why the palms are having better growth in mangrove soil than in nypa palm soil. Field observations also show that the palms produced a lot of seeds as they become adapted to the new environment. In a seed enumeration study in a mixed forest, it was observed that the ratio of the palm seeds to mangrove seeds in a 20 m x 20 m plot was 27:1. This show that the palm seeds in most locations visited out-numbered the mangrove seeds (Fig. 13.19). If this trend continues it won't take too long for the palms to completely overwhelm and colonize the entire region (Wang et al. 2016).

Additionally, continuous anthropogenic disturbance is a major cause of the spread of nypa palms to several other locations after the initial introduction (Kowarik 2003). One of such actions of humans is improper waste disposal within the mangrove forest. This condition makes the environment to be conducive for the palms to grow and proliferate around the coast at the detriment of the mangroves (Fig. 13.20).

Another consequence of urbanization, apart from the physical deforestation of the forest, is the bringing of people closer to the coast so that they will appreciate nature

Fig. 13.20 Waste dump sites in (**a**) nypa palm forest and (**b**) mangrove forest in the Niger Delta, Nigeria. This is one of the consequences of urbanization when people live too close to the coast. The palms grew bigger while the mangroves die gradually with the introduction of waste to the coastal areas. Both areas were exclusively mangrove forest 30 years ago, but continuous dumping of waste converted these areas into a nypa palm (*Nypa fruticans*) forest. (Credit: A.O. Numbere)

better, which is not a bad idea. But the problem is that when people live so close to the coast, and don't have good waste management habit, there is a tendency for them to convert the river to a waste dump site. The coast becomes a victim of increased waste load. In some locations the coast serve as sites for constructing pier latrines especially in the hinter lands where people don't feel the presence of government, in terms of provision of social amenities. The wastes generated when dumped in the river are distributed by tidal currents to other locations. Organic waste when dumped into the river changes the stream chemistry, which leads to eutrophication and increase in growth of foreign species such as water hyacinth, water lilly, macrophytes etc. In Buguma over nine different coastal and non-coastal plant species were found within the mangrove forest. This invasion is as a result of the dredging activity that took place several years ago, which converted the swampy soil to sandy soil (Fig. 13.21).

Fig. 13.21 Different kinds of mangrove and non-mangrove species found in sand filled mangrove forest in Buguma, Niger Delta, Nigeria. (**a**) Nypa palm (*Nypa fruticans*), (**b**) Black mangroves (*Laguncularia racemosa*), (**c**) Conocarpus erectus (**d**) Mangrove associate, (**e**) Red mangrove (*Rhizophora racemosa*) (**f**) Mangrove fern, (**g**) White mangrove (*Avicennia germina*ns), (**h**) *Heriteria littoralis* (**i**) *Acrostichum aureum* spp. (Credit: A.O. Numbere)

13.4.1 Interaction Effect

The combined action of urbanization, improper waste management and pollution (Fig. 13.22) contributes to the proliferation of invasive nypa palms and other alien species in the Niger Delta, Nigeria. These actions are detrimental to the

Fig. 13.22 The interaction effect of (**a**) urbanization and (**b**) hydrocarbon pollution contribute to the proliferation of nypa palms and other alien species in coastal regions of the Niger Delta, Nigeria. Figure 13.22 (**a**) shows houses built after the mangrove forest was cut, dredged and used as site for building residential quarters, Still at the foregound of the picture the remaining mangrove stands had already been invaded by palms and other aliens species while in Fig. 13.22 (**b**) the dark and scorched area is caused by fire from spilled crude oil and on the left of the picture is a nypa palm stand that had already gained a foot hold in the mangrove forest

coastal system because they reduce the aesthetic value and make them vulnerable to total destruction through dredging.

13.4.2 *Impact of Invasive Nypa Palms on Coastal Ecology of the Niger Delta*

The branchless nature of nypa palms excludes a host of coastal organisms that would have benefitted from their presence. For instance, birds can't perch on and build their nest on the palms, which excludes that aspect of the food chain. Similarly, termitarium of termites and nest of ants cannot be found on the palms, since they have no branches and no stem on which to build. Their deep underground roots host little or no shell organisms such as corals, barnacles and mullets. Nypa palms also have low litter fall yearly (Numbere and Camilo 2016), which exclude decomposition activity as experienced in mangrove forest (Numbere and Camilo 2016). In the case where there are a drops of leaves due to wind action, the leaves decompose slowly because of their fibrous nature as compared to mangrove leave litter that is leathery and succulent. One important coastal resource derived from mangroves, apart from fish, is firewood. The palms can't provide it because they lack the stems. The growth of the palms without stem also affects the free movement and distribution of species within the forest. The hard outer covering of the seed (exocarp) makes it difficult for most organisms to feed on it as compared to the tender succulent propagules of mangroves which are consumed by the West African red mangrove crabs (*Goniopsispelii*), and other organism living along the coast.

It was observed from several field trips in this region that the presence of palms in the coastal environment automatically changes the soil chemistry and physical appearance of the soil by converting it to dirty mud. This kind of soil prevents the growth of mangroves and excludes numerous aquatic organisms that usually thrive in mangrove forest swamps. The ability of the palms to trap and accumulate debris within the forest also poses major environmental and ecological problems. This is because the dirty environment makes it less conducive for the breeding and spawning activities of many aquatic organisms especially the fishes.

13.5 Management Strategies

Invasion Control This involves the physical control, which is the destruction of unwanted plants by manual (i.e. digging and pulling) or mechanical (i.e. swamp buggies) methods (Figs. 13.23 and 13.24) or chemical control, which is the use of chemicals such as pesticides and herbicides to destroy alien plants. Biological control involves the enhancement of the genetic quality of native mangrove species through selective production in nurseries to promote robust growth. In addition, the

Fig. 13.23 This area is a creek that was exclusively occupied by mangrove forest some years ago, but have been invaded by the invasive nypa palm (*Nypa fruticans*), which blocked the creek. The palms were destroyed with a swamp buggy to free up the adjoining clogged up canal. (Credit: A.O. Numbere)

Fig. 13.24 This location is the same as Fig. 13.23. It shows a nypa palm resurgence 2 years after the destruction of the forest by swamp buggy. This indicates that the palm stump can proliferate fast if not completely uprooted and destroyed outside the swamp

restored forest is to be filled with core mangrove soils to prevent the negative physicochemical (i.e. allelopathic) effect of nypa palm soil left behind.

Species Based Control This involves experimental research aimed at determining the most effective strategy to embark on based on the particular location. For the nypa palms, studies had shown that, they gain foothold in their new environment by changing the soil chemistry, at the detriment of the host species. Therefore, to eliminate this threat, it is important to remove the nypa palm soils along with the plant completely and to re-introduce mangrove soils to facilitate rapid growth and re-colonization of the area.

Invasion Prevention This involves the identification and regulation of the invasion pathway. For instance dredged spoils, (i.e. waste from dredging activity) that are dumped on fringing mangrove forest can be isolated (Ohimain 2004) and decontaminated of foreign species through heating, chlorination and irradiation etc., to prevent contamination of the host species by invasive nypa palm. This is because "dredged spoil" affects surface topography and hydrology of the coasts (UNEP 2011). Transport trucks and dredging equipments apart from disfiguring the coasts, also carry foreign organisms in soils lodged in their wheels and parts from different locations. Invasion of palms is through dispersal by tidal currents; therefore restored mangrove sites should be fenced off with wire or net gauze to prevent the infiltration of the palm seeds into the newly re-introduced mangrove restoration site.

13.6 Conclusion and Recommendations

Studies had shown that the nypa palms in the Niger Delta had fulfilled the conditions necessary for a successful invasion and colonization. The war therefore, should be taken to them through the adoption of physical, mechanical, chemical and biological method of control. Nypa palm should be removed from all mangrove forests, creeks and coastal areas physically or mechanically using swamp bulldozers. Then their seeds and seedlings should be hand-picked or completely up-rooted and destroyed to prevent resurgence. In 1–3 months time the area should be re-visited and the remaining hidden seedlings that had grown out of the soil pulled out to prevent the re-growth of the palms. The nypa palm soil should be excavated and replaced with mangrove soil before the planting of mangrove seedlings. This is because studies had shown that mangroves don't thrive well on nypa palm soils. The removal of the nypa palm soil will remove the window of opportunity for the re-entry of the palms.

Quick action is therefore, necessary because the palms had already colonized almost a quarter (25%) of the mangrove forest and are in the verge of completely taking over the remaining coastal areas left in the Niger Delta (Fig. 13.25). The palms are advancing rapidly, and if nothing is done, in the next 50 years they might overwhelm and take over the entire coastal areas. But with the timely destruction of the palms and the restoration of mangroves forest, this situation can be turned around for the better.

Fig. 13.25 Nypa palm (*Nypa fruticans*) stands at Asarama River, Niger Delta, Nigeria, overlooking the sea and waiting patiently for an opportunity to take complete control of the mangroves at the adjoining coastal areas. (Credit: A.O. Numbere)

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