Impact of Urbanization on the Evolution of Mangrove Ecosystems in the Wouri River Estuary (Douala Cameroon)

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Chapter 3
Impact of Urbanization on the Evolution of Mangrove Ecosystems in the Wouri River Estuary (Douala Cameroon)

Ndongo Din, Vanessa Maxemilie Ngo-Massou, Guillaume Léopold Essomè-Koum, Eugene Ndema-Nsombo, Ernest Kottè-Mapoko, and Laurant Nyamsi-Moussian

Abstract Cameroon mangroves are protected over 20 years by both Management of Forest and Fauna and Environmental Management Legal Framework laws. However, these juridical tools are not efficient in the field regarding the rate of mangrove forest depletion around coastal cities in the country. This work aims to identify the main factors of mangrove degradation and to assess their effects on the dynamics and evolution of this ecosystem in relation with city development. Key abiotic parameters are favorable for mangrove progression. Natural disasters and anthropogenic activities have been identified as responsible of mangrove ecosystems depletion. Wood harvesting, urban settlement and infrastructures, sand extraction, petroleum exploitation, coastal erosion, and climate change appear to be the most important factors of mangrove degeneration. Secondary destructive factors such as dwellings, sustenance agriculture, collection of Non-Timber Forest Products, digging, landfill, dyke construction and large clear-felling also contributed widely to mangrove degradation. The realization of state projects had heavily impacted the

N. Din (✉) • G.L. Essomè-Koum • E. Kottè-Mapoko • L. Nyamsi-Moussian
Department of Botany, Faculty of Science, The University of Douala, 8948, Douala, Cameroon
e-mail: din.ndongo@yahoo.com; essomekoum@gmail.com; mapokoernest@yahoo.fr; nyamsimoussian@gmail.com

V.M. Ngo-Massou
Department of Biological Sciences, High Teacher's Training College, The University of Yaounde I, 47, Yaounde, Cameroon

Department of Botany, Faculty of Science, The University of Douala, 8948, Douala, Cameroon
e-mail: vanmaxlie@yahoo.fr

E. Ndema-Nsombo
Department of Aquatics Ecosystem's Management, Institute of Fisheries and Aquatic Sciences, The University of Douala, 7236, Douala, Cameroon
e-mail: Ndema_eugene2002@yahoo.fr

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evolution of mangroves in the Wouri river estuary. In the absence of law and specific regulation implementation strategies, populations have taken advantage of the authorities' tolerance to invade all mangroves areas around the Wouri river estuary. The management of Cameroon mangrove ecosystems faced the population conception of considering mangroves as an ordinary forest. Mangrove degradation along the Wouri river estuary does not seem raising advocacy in spite of the fact that this especial ecosystem could never change its coastal nature place like other artificial generated forests.

3.1 Introduction

Mangroves form a complex ecosystem, comprising several interconnected elements at the land-sea interface, which are in turn connected with adjacent coastal ecosystems such as coral reefs, seagrass beds and terrestrial vegetation. Mangrove forests prevent coastal erosion, contribute to the progression of the land towards the sea and react as a buffer in areas prone to cyclone or other ocean surges (Din 2001). In the absence of upwelling on the Cameroon coast, fresh water inputs from rivers and streams constitute the best source of nutrients to the coastal waters. Mangrove ecosystems are opened areas and the movement of materials (organic and mineral) affects not only the composition and structure of plant and animal groups, but also the soil characteristics.

Mangroves supply essential ecosystem services to tropical economies by contributing substantially to timber and charcoal supplies, productivity of near-shore fisheries, ecotourism, etc. (Nfotabong-Atheull et al. 2009). Degradation of natural resources is a major environmental issue that societies around the world are currently facing (Goodman 2010). Mangrove forests are experiencing long-term and severe decline. The rate of the deforestation is high in many developing countries, possibly higher than any other type of tropical forests (Spalding et al. 2010; Giri et al. 2011). The causes of such losses include not only natural disasters and sea-level rise, but also and especially land-use development. The intense human activities within the mangrove area (excessive harvest of mangrove trees for firewood, charcoal, clearing of mangrove areas for agricultural purposes, pollution), coupled with the rapid urbanization of the adjacent towns, have led to a gradual degeneration of these ecosystems (Din et al. 2008; Nfotabong-Atheull et al. 2009, 2013; Fusi et al. 2016). This phenomenon is expected to worsen in the years to come, with the expected vulnerability of mangrove to the rise of the sea level due to the climate change (Duarte et al. 2013; Alongi 2015; Din et al. 2016).

It is projected that anthropogenic climate change is likely to have adverse impacts on African ecosystems and their biodiversity, but projections of impacts based on a range of methodologies diverge widely (Midgley and Bond 2015). These differences relate to the extent to atmospheric CO_2 and disturbance on ecosystem structure and productivity, and relative strengths in accounting for temperature-versus water-related controls on biodiversity. As in certain areas of Africa, Cameroon is characterized by a strong climatic variation since 1960. The rise of pluviometry is palpable on annual, seasonal and monthly scales. Significant studies on variability and the climatic fluctuations in relation to the development and the environment showed rainfall deficits of about 20%. These values might be sometimes higher than 25% on the Atlantic coast and in the forest areas that confirms that "wet" Tropical Africa is regularly under the effect of climatic variability (WTO and UNEP 2008).

In Cameroon, human activities appear to be the main factor influencing the structure and dynamic of mangroves. Mangrove deforestation is occurring at a rate of 1–2% per year, which implies that most forests will disappear within this century (Alongi 2002; Feka and Manzano 2008). These disturbances in mangroves have been attributed to a combination of such factors due to the absence of adequate legislation regarding mangrove protection, and pollution in the peri-urban settings (Nfotabong-Atheull et al. 2013; Fusi et al. 2016). Rapid population growth has affected resources, including arable land, food supplies, water and energy, especially in developing countries where government policy-makers still pay little attention to protect these coastal ecosystems (Dahdouh-Guebas and Koedam 2008; Walters et al. 2008).

Cameroon mangroves are rather protected by both Law n°94/01 of 20th January 1994 on the Management of Forest and Fauna and Law n°96/12 of 05th August 1996 on the Environmental Management Legal Framework. Article 94 of the last law stipulates that "Mangrove ecosystems need particular protection in relation with their importance in the conservation of marine biodiversity and the maintenance of coastal ecologic balances". However, the application of these laws and other specific regulations is not effective in the field and consequently exposes Cameroon coastal natural resources and areas to overexploitation and degradation (Din 2001; Din et al. 2008; Nfotabong-Atheull et al. 2009).

Pollution which is neglected in coastal Africa constitute the principal form of environmental degradation in more industrialized countries. The scarcity of relevant data could justify the lack of interest in the effects of pollutants on mangrove ecosystems functioning. A recent survey shows that the degradation of Cameroon estuarine and marine environment is also due to pollutants (Fusi et al. 2016). The main source of contamination in the mangrove forest surrounding Douala is represented by uncontrolled discharge of urban wastewater and persistent, illegal and indiscriminate use of DDT. These contaminants, together with four specific heavy metals (As, Cr, Zn, Se) seem to affect the macrobenthonic assemblage, suggesting that Douala mangrove is subjected to a complex patchwork of contamination (Fusi et al. 2016).

Urbanization in this context has involved the development of infrastructures and voluntary resettlements. The lack of state and local relevant planning programs, the poverty and the permanent demographic pressure in towns accelerate the depletions easily appreciable on a short time. Mangroves suffer therefore natural and human pressures. Coastal erosion, invasion by weeds, sea-level rise and climate change damage these ecosystems. Massive degradation of mangroves in Cameroon is mostly observed near the coastal cities. High household demands for fuel-wood greatly affect plant populations. Uncontrolled wood cutting, unauthorized settlements, industrial discharges and various organic by-products, sand-pits, irresponsible factory building and warehouses, perpetual extension of sea-port, all have additional negative consequences on the performance of mangrove ecosystems. This work aims to describe the main factors of mangrove degradation and to assess their effects on the dynamics and evolution of this coastal ecosystem.

3.2 Mangrove Characteristics

3.2.1 Mangrove Distribution

Geographically, Cameroon belongs to both central and western Africa. The Atlantic front, with about 400 km long, is located at the southern part of the Gulf of Guinea, imbedded between Nigeria and Equatorial Guinea.

This country has an important biodiversity because of climate and relief variation. Mangrove areas represent about 1–1.5% of the tropical rain forest. Cameroon mangroves border the Atlantic Ocean, and occupy a surface area estimated from 2300 to 2700 km^2. The two main areas of mangroves are in the northern part of the coast. From the mouth of Sanaga river to the one of the Ntem river, mangrove stands are very reduced and could not appear clearly in aerial photographs or satellite imageries. The Rio del Rey estuary mangroves covered between 1400 and 1600 km^2 while the Cameroon Estuary mangroves occupied about 1000 km^2 (Fig. 3.1).

3.2.2 Climate

The climate of the coast of Cameroon is influenced in part by the proximity of both the Atlantic Ocean and Mount Cameroon, and secondly by the permanent presence of the meteorological equator where converge the Azores anticyclone and that of St. Helena. The main geographical factors in rainfall are similar to those generally determine the distribution of climates. It's admitted that in Cameroon, the distribution of climates depends on the precipitations and incidentally the thermal regime which essentially depends on altitude and latitude (Suchel 1972).

The climate is a specific equatorial, with a long rainy season (March–November) and a short dry season (December–February), often punctuated with showers. Rainfall is abundant and regular (more than 200 days of rain per year). Mean annual rainfall reaches 5 m and mean annual temperature is above 26 °C around Douala. Humidity remains high throughout the year (absolute maximum close 100%). In general, wind speed is low except during Saint Helene anticyclone setting phases (March–April), and dies back later in the season (September–October). Winds give almost a constant direction to coastal currents that carry and deposit large amounts of materials (mud, clay, sand). This situation occurs in "the mouths of Cameroon"

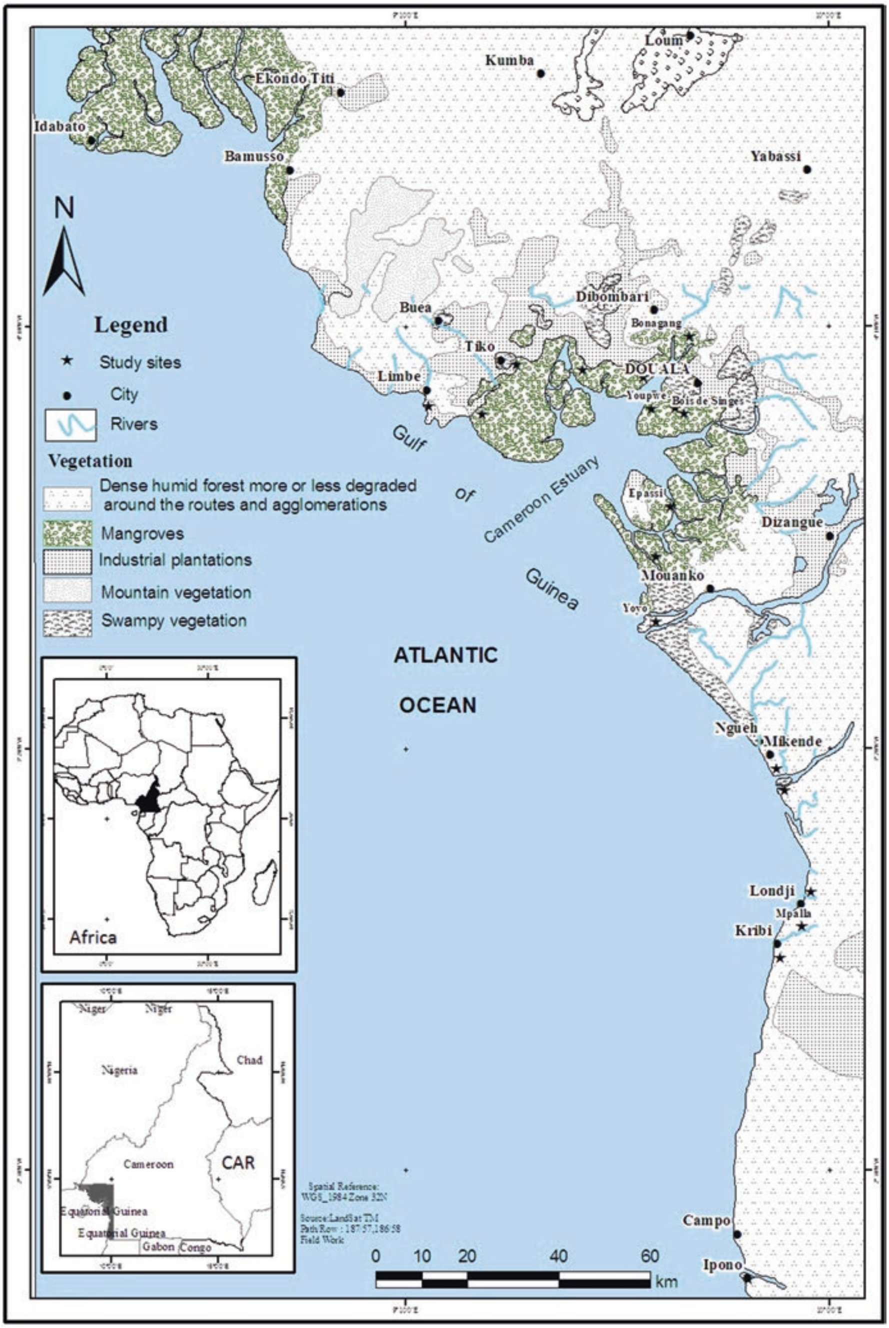

Fig. 3.1 Distribution of mangrove ecosystems in Cameroon coast (Modified after Din et al. 2016)

where silting up obliges the authorities to permanent dredging of Douala Port channel. All climatic parameters in the Wouri river estuary show favorable values for the progressive evolution of mangroves. No element of the climate does not seem likely to act as a limiting factor (Din 2001).

3.2.3 Substrate

Few data on soil analysis are available and this remains a major problem in the study of Cameroon mangroves. However, given the luxuriant vegetation, one can assume that edaphic conditions are favorable for the development of a mangrove forest ecosystem in this zone. The variation in edaphic parameters based on vegetation types was studied in the Wouri estuary mangrove (Abata 1994; Baltzer et al. 1995). The frontier area consists of a clay loam soil with blackish fluid consistency with total absence of litter. The area of young *Rhizophora* spp. growth is characterized by a significant felting roots and rootlets in the surface portion of the core, of fibrous and spongy structure (Fig. 3.2). The floors are dark gray fibrous peat in the first 50 cm and very plastic black undeveloped consistency in depth.

In the *Avicennia germinans* area, litter is thick on surface among many pneumatophores and seedlings (Fig. 3.2). The soil has marbled brown spots, red, gray dark or bright, black and rust along the pneumatophore cavities. In depth, the peat horizon in semi-fluid consistency has morphological relics soil with *Rhizophora*.

Soil on degraded areas of *Rhizophora* and *Acrostichum* are peat with a thin litter regularly moved by the tides. Between 0 and about 80 cm, the fibrous structure is spongy and very compact formed by felting of medium roots and rootlets. The color is reddish brown in surface parts and dark gray to black in depth.

In the *Guibourtia demeusei* area, soils have a medium close rooting soil well drained areas of inland areas. The texture is clayey, lumpy structure developed consistency. The color is dark brown on the surface and deep yellowish brown with gradual disappearance of radial maze of roots. The texture is sandy clay and lumpy structure more or less wet. From 60 cm, the relics of the spongy, fibrous structure of pioneer areas are observe. These horizons are plastic, adhere to semi-developed consistency, waterlogged and with numerous vertical roots of *Rhizophora* in advanced decomposition.

In shrubland of *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Ormocarpum verrucosum* and *Phoenix reclinata*, litter consists of decomposed leaves. In the superficial part, the floors are dark brown color, clay texture and crumb structure developed in consistency while in depth, the mottling of spots appear with color change (dark gray black) and structure (clayey silt) with morphological relics areas with *Rhizophora*.

The texture of mangrove sediments is rarely homogeneous, often characterized by a succession of clay beds on surface and sandy beds in depth or by alternating of these two layers. Because of the permanent flooding by tides, chemical ripening is more advanced than the physical. The pH is very fluctuating between two successive stages of engorgement (high tide) and drying (low tide). These mangrove soils

a

Fig. 3.2 Mangrove substrates under *Rhizophora racemosa* shrubs (**a**) and *Avicennia germinans* trees (**b**)

are generally characterized by a high C/N ratio due to the slowing of the biological activity, induced from anoxia.

A recent work on Cameroon mangrove soils has concerned their morphological characteristics through soil profiles (Fig. 3.3), the description of their physical and chemical characteristics in relation with the degradation level of forest vegetation and the ability to curb the phenomenon of climate change through carbon sequestration. The average stocks of carbon sequestered have been estimated at 2289.33 ± 407 $Mg.ha^{-1}$ in Bamusso (Rio del Rey group) and 2025.89 ± 165 $Mg.ha^{-1}$ in Campo (Ndema-Nsombo et al. 2016).

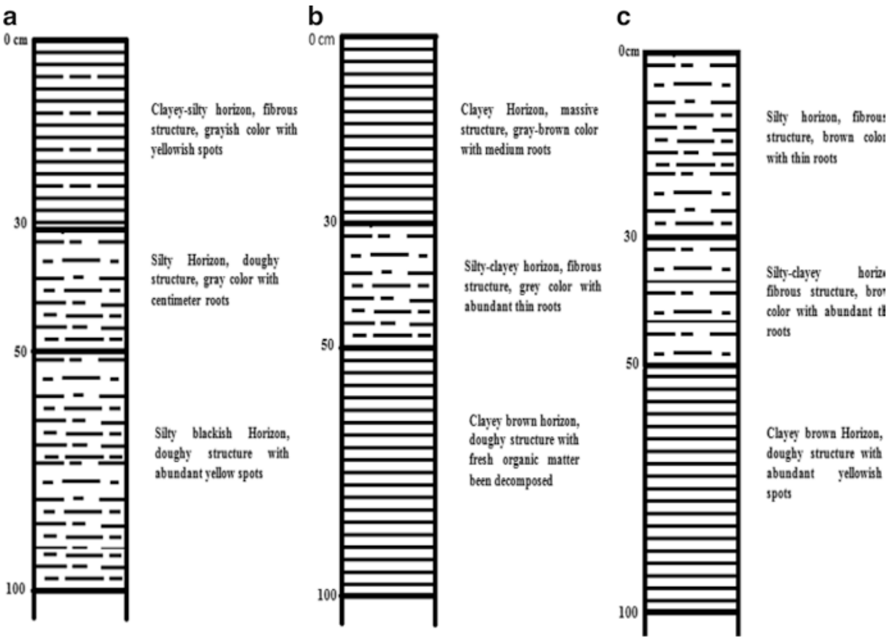

Fig. 3.3 Cameroon mangrove soil profiles: (**a**) Ntem Estuary; (**b**) Cameroon Estuary; (**c**) Rio Del Rey Estuary (Ndema-Nsombo et al. 2016)

3.2.4 Hydrology

The hydrology of Cameroon is influenced among other factors by the general scheme of the Biafra Bay, climate, topography and geomorphology (Olivry 1986). Hydrological conditions of the Biafra bay are relatively stable. The mass of surface water remains warm (25–28 °C) all the year with relatively low salinities (below 35‰). In estuaries, the salinity is still less than 20‰ and dilution is very fast. Less than 30 km from the ocean, salinity is null or almost during the most part of the year.

The estuary waters present a stratification with continental waters dominance, warm and rich in nutrients and sediment loads that float on marine water, saltier, colder and clearer (Baltzer et al. 1995). Coastal rivers constitute two subsets around the Sanaga river, the country main river which drains itself a watershed of about 135,000 km^2, with 920 km in length. During the long rainy season, seawater that waters daily twice these ecosystems is still below 10‰, while in the dry season, it varies between 4 and 20‰. Mangroves of the Cameroon Estuary are constantly watered by brackish water resulting from the dilution of seawater by fresh water from rivers and heavy rainfall.

Tides influence the structure, composition and distribution of mangrove vegetation. Similarly, they affect the salinity of the soil and the evaporation rate. Tide regime is semi-diurnal in Cameroon with a maximum amplitude that is approximately 3 m high in the Douala port (Wouri river). Baltzer et al. (1995) explained the local stability of salinity in the mangrove of Wouri river estuary by the existence of stabilizing factors. Din (2001) associated the distribution of salinity in this estuary with three areas of mangrove vegetation structures:

- Seawaters predominance with a salinity between 15‰ and 20‰ coincide with areas of pioneer vegetation largely dominated by *Rhizophora* spp. and sometimes *Nypa fruticans* in degraded recolonization zones;
- Intermediate waters with a salinity between 5‰ and 10‰ characterize the regressive series composed of small stunted *Rhizophora* generally associated with *Acrostichum aureum* and *Dalbergia ecastaphyllum* or *Hibiscus tiliaceus*;
- Low salinity waters with concentrations between 0‰ and 5‰ sheltered in the river front large *Rhizophora* spp. trees and in the transitional zone, a forest vegetation dominated by *Guibourtia demeusei* or *Cynometra mannii* or species of *Arecaceae* family in degraded areas.

The salinity of soil water is much higher. Important values were found in the *Avicennia germinans* stands. The distribution of forest plant species follows the salinity gradient. True mangrove plants tolerate medium level of salinity while mangrove associate plants are commonly found in low salinity areas (Din et al. 2002). Salinity also varies within the sediments (along a core), the surface portions being less salty.

3.3 Mangrove Composition

Mangrove landscapes in Cameroon are slightly different in structure from other mangrove ecosystems in the Gulf of Guinea, but the composition remain the same. The flora and fauna are not very diversified in comparison with other types of forest in the country.

3.3.1 Flora

The flora of the Cameroon mangroves and associates presents 63 species divided into 54 genera and 29 families. The herbaceous stratum represents less than 1% of all vegetation. There are seven indigenous species consisting of *Acrostichum aureum* L., *Avicennia germinans* (L.) Stearn, *Conocarpus erectus* L., *Laguncularia racemosa* (L.) Gaertn. F, *Rhizophora racemosa* GFW Meyer, *R. harrisonii* Leechman, and *R. mangle* L. *Nypa fruticans* Wurmb. is often considered as an introduced species from Indo-Malaysian mangroves (Din 2001).

These previous species, considered as true mangrove species live in association with others considered like associates (Tomlinson 1986). Most frequent plant species include *Alchornea cordifolia* Müll. Arg., *Annona glabra* L., *Anthocleista* *vogelii* Planch., *Bambusa vulgaris* Schrad. ex J.C. Wendn., *Cocos nucifera* L., *Cynometra mannii* Oliv., *Dalbergia ecastaphylum* (L.) Taub., *Drepanocarpus lunatus* GFW Meyer, *Elaeis guinensis* Jacq., *Eremospatha wendlandiana* Dammer ex Becc., *Hibiscus tiliaceus* L., *Guibourtia demeusei* (Harms) J. Léonard, *Ormocarpum verrucosum* P. Beauv., *Pandanus candelabrun* P. Beauv., *Paspalum vaginatum* Sw, *Phoenix reclinata* Jacq., *Raphia palma-pinus* (Gaertn.) Hutch., *Sesuvium portulacastrum* L., etc.

The diversity in mangrove ecosystems can be expressed in terms of types of vegetation encountered. The flora of the Wouri river estuary mangrove is made in the suburban area of monospecific stations dominated widely by *Rhizophora* spp. while *Avicennia germinans* and especially *Nypa fruticans* succeeded in large deforested areas. The next group, a blend of trees, shrubs, palms and grass, appears more diversified, consisted of *Acrostichum aureum*, *Cynometra mannii*, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Ormocarpum verrucosum*, *Pandanus candelabrum*, *Phoenix reclinata*, *Raphia palma-pinus*, etc. which are associations of plants generally observed along the edges slightly muddy (Din 2001; Nfotabong-Atheull et al. 2013).

In the peri-urban areas, mangroves are converted into agricultural fields in which there are species such as *Zea mays* L., *Phaseolus vulgaris* L., *Elaeis guineensis* Jacq., *Musa* spp., *Saccharum officinarum* L. Other observations show that change of land use promotes presence of unusual species. This is among other: *Paspalum vaginatum*, *Anthocleista vogelii*, *Sesuvium portulacastrum*, and *Alchornea cordifolia*. The presence of these species in the intertidal zone is justified by physicochemical changing properties of the soil due to scarcity of water in these places once regularly flooded (Nfotabong-Atheull et al. 2013).

The structure of mangrove forest always characterizes this ecosystem worldwide by an organization of vegetation based on distinct bands or zones, parallel to the shore of the main water channel and each zone usually dominated by a single plant species or rarely a combination of two plant species (Tomlinson 1986; Din 2001; Marchand 2007; Din and Baltzer 2008; Nfotabong-Atheull 2011). The structure of the Wouri river estuary mangroves is especial in the dimensions of trees (Fig. 3.4). *Rhizophora* species have trees which can grow up to 50 m height in mature and undisturbed forest while *Avicennia germinans* trees have shown diameters upon 100 cm (Din and Baltzer 2008; Din et al. 2002).

In many places, mangrove ecosystems of the Wouri river estuary have presented a complete progressive series from pioneer stage to almost climax stands. The physiognomy of mangrove vegetation has been characterized by four landscapes (Fig. 3.5):

1. the pioneer vegetation is consisted of *Rhizophora* seedlings and shrubs which grow on an unstable substrate in the accretion areas installed in the center or on the edges of the river and channels. After the depletion of the mangrove forest, a recolonization is observed on abandoned and temporally flooded areas. *Nypa fruticans* generally dominated this stage and the evolution led to transform the original mangrove vegetation features;

Fig. 3.4 Measurement of mangrove tree structure parameters: (**a**) *Rhizophora* zone; (**b**) *Avicennia* zone

2. on the concave edges (accretion zones), after the pioneer stands, a monospecific wide band of *Rhizophora* spp. with tall individuals exceeding 40 m in height extends sometimes on hundreds of meters. Inside the opened forest, this species often formed mixed stands with giants *Avicennia germinans* and thickets *Nypa fruticans*;
3. the convex banks (erosion areas) are characterized by consolidated substrate consisted of low alluvial deposits. *Acrostichum aureum* is tightly mixed with

Fig. 3.5 Landscapes of Cameroon mangrove vegetation. (**a**) Pioneer progressive area; (**b**) recolonization by *Nypa fruticans*; (**c**) tall individuals of *Rhizophora* spp.; (**d**) setting up of *Avicennia germinans* band; (**e**) open forest with *Rhizophora* spp. (*background*) and *Acrostichum aureum* (*front*); (**f**) very low flooded swampy forest with *Pandanus* sp.

shrubs and short trees of *Rhizophora* spp. characterized by dwarfed and tortuous stems. The inner part of this zone is generally opened and often invaded by shrubs and young trees of *Conocarpus erectus*, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Laguncularia racemosa*, *Ormocarpum verrucosum*;

4. the back mangrove areas or transitional zone looks like any tropical swamp forest marked however by the continuous presence of mangrove characteristic spe-

c
d


Fig. 3.5 (continued)

cies among swampy forest species. The last band is a low flooded area occupied mainly by species of *Annona glabra*, *Anthocleista vogelii*, *Cynometra mannii*, *Guibourtia demeusei*, *Pandanus candelabrum*, *Phoenix reclinata*, *Raphia palma-pinus*, and few true mangrove forest species.

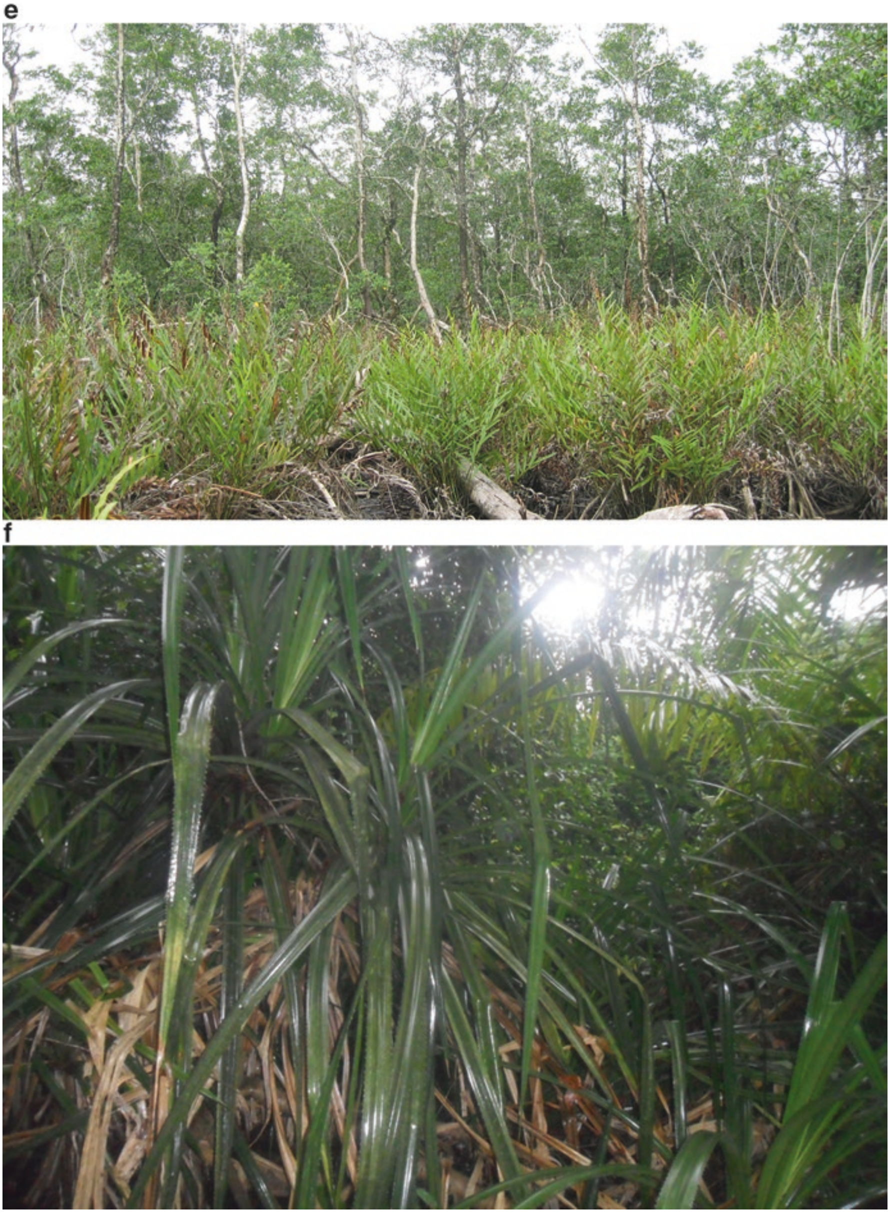

Fig. 3.5 (continued)

3.3.2 Fauna

Mangrove forests play a crucial role in providing suitable habitats for fauna, safe breeding and chick rearing grounds, nurseries for a diversity of fishes and shellfishes, as well as ideal foraging grounds for animals such as fishes, birds and aquatic invertebrates and refuge from predators (Macintosh et al. 2002). Faunal assemblages of mangroves are significantly less studied and documented than the forests they inhabit (Lee 2008). Animals found within mangrove environments include a variety of taxa, many of which are vulnerable or threatened as a result of human activities in the coastal zone (Nagelkerken et al. 2008). Some of the animals depend on mangrove areas their whole lives while others utilize them only during specific periods such foraging, shelter and breeding (Nyanti et al. 2012).

3.3.2.1 Invertebrates

Invertebrates break down leaf litter that act as fertilizer (Smith 1987), increase surface area of mud through burrowing (Kristensen 2008; Penha-Lopes et al. 2009) and increasing the diffusion rate of gases (Lee 1998) that ultimately affect the growth and productivity of the mangrove vegetation (Nielsen et al. 2003; Kristensen and Alongi 2006). In the Wouri river estuary mangroves as worldwide, the well-known invertebrates are crabs and molluscs. They are the predominant taxa in mangrove forests and are thought to play a significant ecological role in the structure and function of this ecosystem (Cannicci et al. 2008; Ngo-Massou et al. 2012). They form an important link between the primary detritus at the base of the food web and consumers of higher trophic levels (Sousa and Dagremond 2011).

Crabs

Many researchers were interested by mangrove crabs in Cameroon (Boyé et al. 1975; Guiral et al. 1999; Longonje 2008; Longonje and Raffaelli 2013; Ngo-Massou et al. 2012, 2014, 2016). Din et al. (2014) have presented a review of mangrove crabs evolution in Cameroon. The data have shown 33 species recorded grouped into 19 genera and 10 families (Table 3.1). Ongoing surveys (unpublished data) have improved these results with more species and new families of crabs in the coastal Atlantic mangroves of the country (Fig. 3.6).

Molluscs

Abundance and biomass of molluscs in mangrove habitats can be equally impressive than brachyuran crabs (Nagelkerken et al. 2008), although the number of comparative studies on mollusc diversity and structure in Cameroon mangroves is limited (Plaziat 1974; Boyé et al. 1975; Bandel and Kowalke 1999; Guiral et al.

Table 3.1 Mangrove crab species found in Cameroon

Family	Genera	Scientific name
Gercacinidae	*Cardisoma*	*Cardisoma armatum*
		Cardisoma guanhumi
Grapsidae	*Goniopsis*	*Goniopsis cruentata*
		Goniopsis pelii
	Grapsus	*Grapsus grapsus*
	Pachygrapsus	*Pachygrapsus transversus*
		Pachygrapsus gracilis
		Pachrygrapsus sp. 2
Macrophthalmidae	*Macrophthalmus*	*Macrophthalmus* sp.
Majidae	*Maja*	*Maja squinado*
Ocypodidae	*Ocypode*	*Ocypode africana*
		Ocypode cursor
		Ocypode ippeus
	Uca	*Uca tangeri*
Panopeidae	*Eurypanopeus*	*Eurypanopeus Blanchardi*
	Panopeus	*Panopeus africanus*
Pilumnidae	*Pilumnopeus*	*Pilumnopeus africanus*
Potunidae	*Callinectes*	*Callinectes amnicola*
		Callinectes pallidus
	Portunus	*Portunus validus*
Sesarmidae	*Armases*	*Armases elegans*
	Chiromantes	*Chiromantes buettikoferi*
		Chiromantes angolense
	Metagrapsus	*Metagrapsus curvatus*
	Perisesarma	*Perisesarma alberti*
		Perisesarma huzardi
		Perisesarma kamermani
	Sesarma	*Sesarma* sp. 1
		Sesarma sp. 2
		Sesarma sp. 3
		Sesarma sp. 4
Varunidae	*Helice*	*Helice* sp.

Modified after Din et al. (2014)

1999; Ngo-Massou et al. 2012). However, these works have provided relevant data concerning essentially the distribution of molluscs in the Cameroon Atlantic coast (Table 3.2). A relative recent census found 12 species among which 11 gastropods and one unknown species of bivalves (Ngo-Massou et al. 2012).

Throughout most mangrove habitats, molluscs live on and in the muds, firmly attached to the roots, or forage in the canopy. They occupy a number of niches and contribute to the ecology of the mangal in important ways (Kathiresan and Bingham 2001). The composition of molluscan community in Wouri estuary river mangrove forest consist of two main taxa as Gastropods and Bivalves (Fig. 3.7).

Fig. 3.6 Mangrove crab species encountered in Cameroon ecosystems

Table 3.2 Species of molluscs found on mangrove areas of Cameroon. Ongoing studies have found many undefined species (not present in this document) in order to improve the database

Species	Plaziat (1974)	Boyé et al. (1975)	Bandel and Kowalke (1999)	Guiral et al. (1999)	Ngo-Massou et al. (2012)	Ongoing research
Achatina achatina	–	–	–	–	+	+
Anadara senilis	–	–	–	+	–	–
Angiola lineata	–	–	+	–	–	–
Arca sp.	+	–	–	–	–	–
Assiminea hessei	–	–	+	–	–	–
Bivalve (Unknown)	–	–	–	–	+	–
Corbula trigona	+	–	–	+	–	–
Crassostrea gasar	+	–	–	+	–	+
Cyrenoida rosea	+	–	–	+	–	+
Cyrenoida rufa	+	–	–	–	–	–
Cyrenoida senegalensis	–	–	–	+	–	–
Egeria radiata	+	–	–	–	–	+
Fissurela sp.	+	+	–	–	–	–
Iphegenia deleserti	–	–	–	+	–	–
Iphegenia leavigata	–	–	–	+	–	–
Iphegenia rostrata	+	–	–	–	–	+
Littorina (Scabra) angulifera	+	+	+	–	–	+
Littorina sp.	–	–	–	–	–	+
Melampus liberianus	+	+	+	+	–	–
Melanoides pergracilis	–	–	–	–	+	+
Melanoides tuberculata	–	–	+	–	+	+
Melanopsis sp.	–	–	–	–	–	+
Murex sp.	–	–	–	–	–	+
Mytilopsis africana	–	–	–	+	–	–
Neritilia manoeli	–	–	+	–	–	–
Neritilia rubida	–	–	+	–	–	+
Neritina afra	–	–	+	–	–	–
Neritina glabrata	+	+	+	+	–	+
Neritina lineolata	–	–	–	–	–	+
Neritina oweniana	–	–	–	+	–	–
Neritina rubricata	–	–	+	–	–	–
Neritina senegalensis	+	+	–	+	–	+
Onchidium sp.	–	+	–	–	–	–
Ostrea tulipa	+		–	–	–	–
Pachymelania aurita	+	–	+	+	+	+

(continued)

Table 3.2 (continued)

Species	Plaziat (1974)	Boyé et al. (1975)	Bandel and Kowalke (1999)	Guiral et al. (1999)	Ngo-Massou et al. (2012)	Ongoing research
Pachymelania byronensis	–	+	+	+	–	+
Pachymelania fusca	+	–	+	+	+	+
Pachymelania Granifera	–	–	–	–	+	+
Pachymelania mutans	–	–	–	–	–	+
Pachymelania sp.	–	–	–	–	+	+
Potadoma lirincta	–	–	–	–	+	+
Potamopygus ciliatus	–	–	+	–	–	–
Pupura callifera	+	–	–		–	–
Pupura yetus	+	–	–	–	–	–
Scabra scabra	+	+	–	–	–	–
Semifusus moris	–	+	–	+	–	–
Sepia officinalis	+	–	–	–	–	–
Siphora mouret	+	–	–		–	–
Tangelus angulatus	–	–	–	+	–	–
Tectarius granosus	+	+	–	–	–	–
Terebralia palustris	–	–	–	–	–	+
Thais callifera	+	+	–	+	–	+
Theodoxus niloticus	–	–	–	–	+	+
Theodoxus sp.	–	–	–	–	–	+
Thiaridae (Unknown species)	–	–	–	–	–	+
Tympanotonus fuscatus	+	–	+	+	+	+
Tympanotonus radula	–	–	+	–	+	+

Other Invertebrates

Invertebrates as Insects, Annelids and other Crustaceans (prawns, shrimps) are inhabitants of mangrove forest, but there is not data about these invertebrates in mangroves of Wouri estuary river. Although the mangal may be a sink for settlement and early growth of shrimp and prawns, it may also be a source for larvae that are transported to other habitats (Kathiresan and Bingham 2001).

3.3.2.2 Mangrove Vertebrates

The distribution of the mammals in the mangroves is hardly better known. The West African Manatee (*Trichechus senegalensis*) occurred in the Wouri river estuary can be considered as one of the most sanctuaries of Manatee in Cameroon coast. The

Fig. 3.7 Some mangrove characteristic species of molluscs found in Cameroon

specie is common in rainy season. Since several years, the manatee is faced to many threats (Ayissi and Jiofack 2014). The carnivores are rather rare; all the species of monkeys are arboreal. The existence of Whales and Dolphins along Cameroon coast is known, but the species distribution is unknown (Ayissi et al. 2011). Whereas some species can be more or less frequently observed, others are much rare and make only incursions of short duration into the mangrove forest.

Mangrove waterways are rich fishing grounds and many commercial species can be found. The most frequently encountered species are: *Ilisha africana*, *Sardinella maderensis*, *Caranx* spp., *Tilapia* spp., *Dentex congolensis*, *Arius* spp., *Pomadasys* spp. and *Periophtalmus papilio*, the mud skippers (Fig. 3.8).

Fig. 3.8 *Periophtalmus papilio*, the most characteristic mangrove fish

Four species of sea turtles are common along the Cameroon coast: Leatherback turtle (*Dermochelys coriacea*), Green turtle (*Chelonia mydas*), Olive ridley (*Lepidochelys olivacea*) and Hawsksbill (*Eretmochelys imbricata*). But, just Green turtle and Hawskbill are common on mangroves (Ayissi and Jiofack 2014). These turtle species utilize mangrove areas for foraging and breeding purposes due to the richness and diversity of plankton and benthic food resources.

Few crocodile species exist in mangroves, estuarine, and adjacent rivers (Rajpar and Zakaria 2014), but the presence of species such as *Crocodilus niloticus* and *Ostealaemus tetrapis* all classified like species in danger by IUCN is surmised. A wide array of animals such as birds, fishes and mammals are prey of these crocodile species. Other reptiles founded are snakes and mangrove monitor lizard (*Varanus niloticus*).

The mangrove habitat plays a host role to a moderate number of bird species around the globe. Hundreds of bird species migrate to the mangrove forest for feeding, roosting, nesting and breeding, certain species are dependent on the mangrove ecosystem and they also play a vital role in maintaining the mangrove ecosystem through several activities mainly those of pollinator, seed disperser, and pollution regulation providing food for other animal predators and also contributing to nutrient recycling processes. However, few animals have been reported to feed on mangrove trees directly, whereas other parts of the mangrove, like dead leaves, stems and roots (Rohit et al. 2016).

Van der Waarde (2007) have found 300 birds along Cameroon coast among which less than a hundred of species are present in mangrove areas (Table 3.3). The water birds reported were categorised into four groups:

– Cormorants to Ibises which counted Little Egret, Grey Heron, Great Egret, African Openbill storks, White pelican, Pink-backed Pelican (*Pelecanus rufescens*),

Table 3.3 Water birds found in Cameroon mangrove areas

Family	Scientific name	Common name
Anatidae	*Dendrocygna viduata*	White-faced Whistling Duck
Anatidae	*Plectropterus gambensis*	Spur-winged Goose
Anatidae	*Pteronetta hartlaubii*	Hartlaub's Duck
Anatidae	*Nettapus auritus*	African Pygmy Goose
Anhingidae	*Anhinga rufa*	African Darter
Ardeidae	*Ardeola ralloides*	Squacco Heron
Ardeidae	*Bubulcus ibis*	Cattle Egret
Ardeidae	*Butorides striatus*	Green-backed Heron
Ardeidae	*Egretta gularis*	Western Reef Heron
Ardeidae	*Egretta garzetta*	Little Egret
Ardeidae	*Mesophoys intermedia*	Intermediate Egret
Ardeidae	*Casmerodius albus*	Great White Egret
Ardeidae	*Ardea purpurea*	Purple Heron
Ardeidae	*Ardea cinerea*	Grey Heron
Ardeidae	*Ardea melanocephala*	Black-headed Heron
Ardeida	*Ardea goliath*	Goliath Heron
Burhinidae	*Burhinus senegalensis*	Senegal Thick-knee
Charadriidae	*Charadrius dubius*	Little Ringed Plover
Charadriidae	*Charadrius hiaticula*	Ringed Plover
Charadriidae	*Charadrius marginatus*	White-fronted Plover
Charadriidae	*Pluvialis squatarola*	Grey Plover
Charadriidae	*Vanellus albiceps*	White-headed Lapwing
Ciconiidae	*Anastomus lamelligerus*	African Openbill Stork
Ciconiidae	*Ciconia episcopus*	Wolly-necked Stork
Ciconiidae	*Mycteria ibis*	Yellow-billed Stork
Glareolidae	*Glareola cinerea*	Grey Pratincole
Heliornithidae	*Podica senegalensis*	African Finfoot
Jacanidae	*Actophilornis africanus*	African Jacana
Laridae	*Larus fuscus*	Lesser Black-backed Gull
Laridae	*Larus cachinnans*	Yellow-legged Gull
Laridae	*Sterna nilotica*	Gull-billed Tern
Laridae	*Sterna caspia*	Caspian Tern
Laridae	*sterna maxima*	Royal Tern
Laridae	*Sterna sandvicensis*	Sandwich Tern
Laridae	*Sterna hirundo*	Common Tern
Laride	*Sterna albifrons*	Little Tern
Laridae	*Chlidonias niger*	Black Tern
Laridae	*Rynchops flavirostris*	African Skimmer
Pelecanidae	*Pelecanus onocrotalus*	Great White Pelican
Pelecanidae	*Pelecanus rufescens*	Pink-backed Pelican
Phalacrocoracidae	*Phalacrocorax africanus*	Long-Tailed Cormorant
Podicipedidae	*Tachybaptus ruficollis*	Little Grebe

(continued)

Table 3.3 (continued)

Family	Scientific name	Common name
Rallidae	*Amaurornis flavirostris*	Black Crake
Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt
Recurvirostridae	*Recurvirostra avosetta*	Pied Avocet
Scolopacidae	*Calidris alba*	Sanderling
Scolopacidae	*Calidris minuta*	Little Stint
Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper
Scolopacidae	*Philomachus pugnax*	Ruff
Scolopacidae	*Gallinago gallinago*	Common Snipe
Scolopacidae	*Limosa limosa*	Black-tailed Godwit
Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit
Scolopacidae	*Numenius phaeopus*	Whimbrel
Scolopacidae	*Numenius arquata*	Eurasian Curlew
Scolopacidae	*Tringa tetanus*	Common Redshank
Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper
Scolopacidae	*Tringa nebularia*	Common Greenshank
Scolopacidae	*Tringa ochropus*	Green Sandpiper
Scolopacidae	*Tringa glareola*	Wood Sandpiper
Scolopacidae	*Tringa hypoleucos*	Common Sandpiper
Scolopacidae	*Arenaria interpres*	Ruddy Turnstone
Scopidae	*Scopus umbretta*	Hamerkop
Threskiornithidae	*Bostrychia hagedash*	Hadada Ibis
Threskiornithidae	*Threskiornis aethiopicus*	Sacred Ibis

Modified after Van der Waarde (2007)

Squacco Heron, Green-backed Heron and Sacred Ibis mainly concentrate in the Ndian Basin and Wouri estuary, the two main mangrove areas of the country;
– Ducks, Rails and Fin foots: in this group the Hartlaub's Ducks were found mainly around Sanaga river;
– Waders, the well represented group on the Cameroon coast which included Palearctic species such as Common Greenshank, Common Redshank, Curlew sandpiper and Common Ringed Plover. This group also counted the Grey Pratincole.
– Gulls, Terns and African Skimmer which are the most dominant group of water birds on Cameroon coast represented by Royal Tern and African Skimmer.

Mangrove fauna often show vertical and horizontal zonation. Some of them dominate in mud, some on the shrubs and leaves and the others around roots (Mauris 2005) and can be divided into three inhabitants such as (i) aquatic animals, (ii) semi-aquatic animals and (iii) terrestrial animals based on their living behaviour. These animal communities utilize mangrove areas for their daily activities such as foraging, breeding, and loafing. These animals play a significant role in the management of mangrove forests and in balancing nature in and around the mangrove areas (Spalding et al. 2010; Nyanti et al. 2012).

3.4 Major Factors of Mangrove Degradation

More than 90% of world's mangroves are located in developing countries where impoverished human populations depend on their resources for subsistence (Duke et al. 2007; Walters et al. 2008). Human impacts on mangroves, including climate change, have received much attention of late mainly because mangrove deforestation is occurring at a rate of 1.2% per year, which implies that most forests will disappear within this century (Alongi 2002, 2015). At a global level, natural and anthropogenic drivers of mangrove destruction and degradation include sea-level rise, the harvest of forest products for local (wood, charcoal, and tannins) and industrial (woodchips and lumber) consumption, conversion of mangrove forests into agricultural, aquacultural, industrial and urban areas (Di Nitto et al. 2008, 2014; Rakotomavo and Fromard 2010; Paul and Vogl 2011; Goessens et al. 2014; Santos et al. 2014) and other activities such as river damming and herbicide use (Abuodha and Kairo 2001; Koedam et al. 2007).

In Cameroon, natural disasters and several anthropogenic activities have been identified in relation with mangrove ecosystems depletion. Wood harvesting, urban infrastructures, fishing, sand and gravel extraction, conflicts, petroleum exploitation, coastal erosion, climate change, invaded aquatic plants and agriculture appear to be the most important factors of mangrove degeneration. In addition, most of these parameters are making place to secondary destructive factors, generally linked to poverty such as dwellings, livestock, sustenance agriculture, collecting Non-Timber Forest Products, digging, landfill, dyke construction and large clear-felling which also contributed widely to mangrove degradation (Din 2001; Feka and Manzano 2008; Nfotabong-Atheull et al. 2009; Din et al. 2016; Fusi et al. 2016; Ngo-Massou et al. 2016).

3.4.1 Logging

This activity began in the mangroves of Cameroon at the dawn of the twentieth century (Din et al. 2008). In 1919, a French company based in Manoka devastated the Cameroon mangrove estuary for the home country needs. In less than a decade, more than 3000 tons of wood were sold in the form of railway sleepers. The consequences of this activity are still visible in this borough.

The recent introduction of modern transportation and cutting equipments has accelerated the degradation of several primary formations. Mangroves of the Wouri estuary are strongly flattened. *Rhizophora* spp., flammable species fresh, are most at risk followed by *Avicennia germinans*. Several species of mangrove forests generally have a very hard wood which is flammable fresh and this feature causes the cutting of trees still standing and accelerates the degradation of the forest. The modern sector degradation and the urban demographic pressure induced poverty which increase the number of loggers and consumers who cannot buy kerosene or cooking gas.

In the 1990s, loggers organized clandestine microenterprises in order to destroy Wouri estuary mangrove ecosystem. In addition, they did not pay any taxes although they realized real incomes above the national average. Mangroves wood markets in Douala are found throughout the city. The most important are Bobongo, Youpwe, Deido, Bonaberi. At Tiko, mangrove wood is widely used in households. Firewood is also used by fishermen for drying fish. This is visible in all the fishing camps, even in the localities of the estuary of the Rio del Rey (Ekondi Titi, Bamusso, Meme, Andokat) where tree operating traces are well marked. In Kribi mangroves, collecting timber carried on a small scale is highly selective and often regard the straight trunks of small diameter which are suitable for the construction of precarious homes.

Loggers in the mangroves of Cameroon priority choose *Rhizophora* spp. for firewood and *Avicennia germinans* for lumber. By cons, they slaughter daily without discrimination all other species. Excessive cutting of forests in some mangrove background areas usually leads to the development of low vegetation not erect port. These dense thickets of *Hibuscus tiliaceus* associated with *Dalbergia ecastaphyllum*, *Acrostichum aureum*, *Drepanocarpus lunatus*, *Ormocarpum verrucosum*, etc. adverse shaded form clumps in the establishment of new propagules. In addition, the slaughter intensified of mature mangroves on mudflats in major or intermediate submersion often suggests a new landscape characterized by a canopy punctuated by gaps.

The wood exploitation constitutes one of the main reasons for the degradation of mangrove in the world. Almost 53.216 ha of the Cameroon's mangrove forests have been lost over the last 13 years (Spalding et al. 2010). The mangrove trees are used as an important or potential source of firewood and charcoal, in response to the increase in domestic needs of energy by urban populations in developing countries. Wood appropriation in the mangroves remains an activity which is fully controlled by the informal sector causing that ecosystem to lose its market value.

Mangrove wood is perceived and estimated as the major disruptive factor in the Cameroon estuary ecosystems. Wood extraction resulted mainly from domestic needs of neighboring city dwellers and fish smoking hearths installed inside mangrove camps (Fig. 3.9). Since the both last decades, significant changes in mangrove vegetation (diversity and structure) were observed in Wouri river estuary stands (Din et al. 2008; Nfotabong-Atheull et al. 2009, 2013). The large disturbed mangrove forests found in the early 1990s, which were easily accessible by foot, had been progressively clear-cut from the landward margin toward the main water channels. The degraded areas were subsequently developed for housing. Some areas like Youpwe, Mboussa Essengue, Wouri bridge, Bon'Ewonda and many areas in Bonaberi have been strongly affected and the rapid population increase has especially lead to large-scale deforestation due to a growing demand for housing land and logging cultivation (Din et al. 2008).

Rhizophora spp. is dominant and strongly marketed or directly used in the households for subsistence needs (Feka et al. 2009). Exploitation of mangroves for fuel wood, charcoal production, construction and other uses have been identified as an important pervasive and intrusive threat to this ecosystem (Feka and Manzano 2008). With about 350 loggers estimated in Douala mangrove areas, daily quantity of wood harvested from this ecosystem was about 500 m^3 and revenues was estimated around 11,500 USD (Din et al. 2008).

a

b

Fig. 3.9 Mangrove wood exploitation in Cameroon. (**a**) Irregular logging using motor chain-saws; (**b**) pile of poles for cooking and building; (**c**) collection of planks inside mangrove forest; (**d**) Mangrove wood service waiting for transportation to urban area

Fig. 3.9 (continued)

3.4.2 Sand Quarries

The exploitation of sand is one of the important activities in the mangrove, mainly around large cities. Sand quarries are visible throughout the estuary of Cameroon, particularly around the city of Douala (Youpwe, Bonaberi, Bonamouang, Bonagang, Bon'Ewonda and others) with an annual mangrove sand production estimated at 90,000 m^3. Unlike logging, it does not only affect the vegetation but can cause disturbances in the structure or even the nature of the substrate. This activity is practiced in low tide, which degrades the quality of the water or coves on previously bare soil, thus causing degradation of the environment. This activity is becoming increasingly important in Cameroon estuary (Fig. 3.10) due to the ever increasing demand of export sand towards Equatorial Guinea.

The surroundings and the main river beds are mined mainly in Douala and Tiko. The amount of sand taken is important and mangrove areas especially offer a wide variety of sand quality (fine sand to pebbles). In the 1990s, over 50% of the sand used in the city of Douala for various constructions derived from mangrove areas (Din 2001). The sand mining appeared to be an important economic activity which involved both the informal sector and dredging societies from public works. When

Fig. 3.10 Sand quarry in Douala degraded mangrove forest (**a**) partition of sands and gravels operation near a channel; (**b**) loading of a truck with mangrove sand near *Rhizophora* and *Avicennia* trees

the exploitable areas were detected, trees were felled in a radius of several hundreds meters. The waterways are being diverted or simply blocked. The immediate consequence is the drying of all the area to be harvested and also the whole rear portion which was fed by these pathways. Mangrove characteristic species are very sensitive to daily flooding by tides; stopping the water flow always triggers in short term, the degeneration of the forest composition and structure.

Sandpits change the structure and physiognomy of mangrove ecosystems. Attempts to regenerate mangroves observed in many quarries show that the destruction of mangrove forests due to this activity may be reversible if brackish water supply is restored degraded substrates. The new progressive series is always lead by *Nypa fruticans* but had never evolved to a climaxic mangrove forest.

3.4.3 Landed Distribution

Mangrove forests are experiencing long-term and severe decline (Valiela et al. 2001; Alongi 2002). The causes of such losses include the coastal land-use development leading to losses due to over-harvesting (Walters et al. 2008; Nfotabong-Atheull et al. 2009), expanded agriculture (Hossain et al. 2009), and conversion into shrimp farming ponds (Guimarães et al. 2010), to name but a few. From 1974 to 2009, mangrove forest area had decreased 53.16% around Douala concurrent with a substantial increase of settlements (60%), roads (233.33%), agriculture areas (16%), non-mangrove areas (193.33%), and open water (152.94%) (Nfotabong-Atheull et al. 2013). Deforestation appears to be one of the most ubiquitous forms of land degradation worldwide. Although remote sensing and aerial photographs can supply valuable information on land/use cover changes, they may not regularly be available for some tropical coasts (*e.g.*, Cameroon estuary) where cloud cover is frequent.

While the drivers causing this depletion/deforestation vary from one region to another, there is a general consensus that anthropogenic activities are the root drivers of this change. In addition, while the dilemma of mangrove ecosystem conversion for aquaculture is recognized as the greatest threat to mangrove forests, globally pollution, agriculture and urbanization seem to be making headway among developing countries. Furthermore, exploitation of mangroves for fuel wood, charcoal production, construction, and other uses have been identified as an important pervasive and intrusive threat to this ecosystem (Dodman et al. 2006), particularly within coastal developing countries, where local communities depend on the exploitation and use of these resources for their livelihoods (Focho et al. 2001).

Douala is the first most populous city in Cameroon, with a population that grew rapidly from 1,352,833 inhabitants in 1987 to 2,510,263 people in 2005 (Cameroon National Institute of Statistics 2009). The characteristic urban anarchic development, accompanied by demographic pressure in the peri-urban areas and emphasized by increase in poverty contributed hardly to forest depletion. This growth rates indicate an intense human pressure on the urban landscape. This expansion was therefore the driving factor for the "colonization" of new lands in spite of their physically hostile nature (Fig. 3.11).

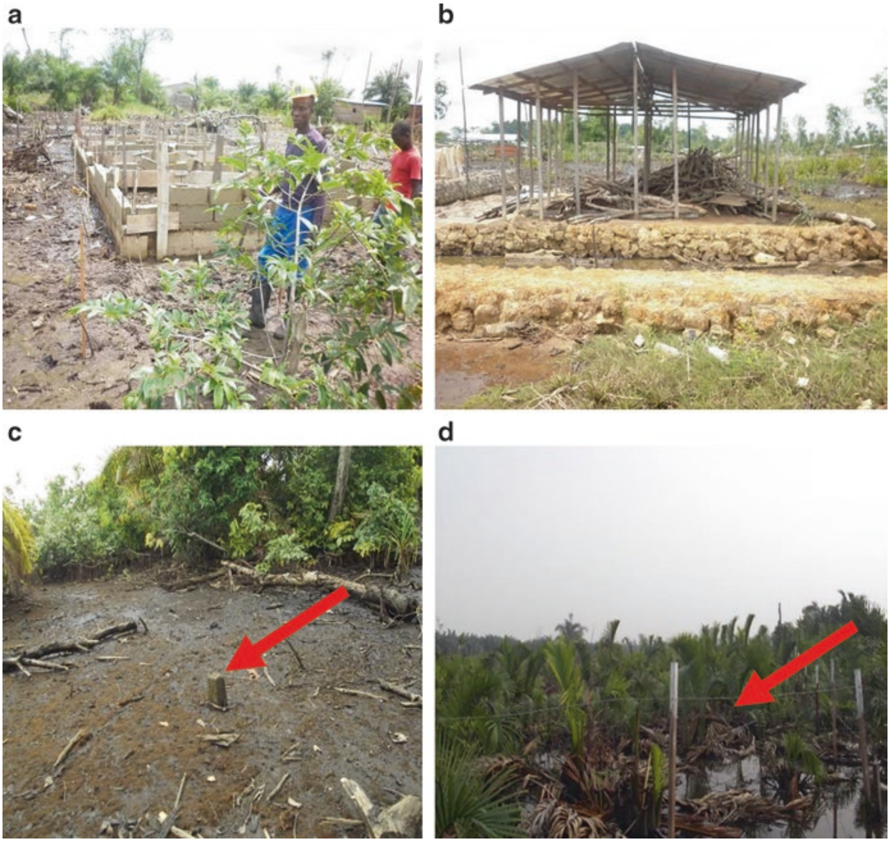

Fig. 3.11 Constructions in the mangrove areas (**a**) definitive material; (**b**) precarious material; (**c**) implanted boundary stone; (**d**) boundary line surrounded young *Nypa fruticans*

3.4.4 Anarchic Urbanization

The majority of coastal communities are dependent on the surrounding mangroves for both subsistence and commercial uses (Din et al. 2008; Nfotabong-Atheull et al. 2009, 2011). Here, mangroves are under severe pressure from housing development, agriculture, sand quarrying, road construction, lumber harvesting, and seaport maintenance and expansion. Actually, Douala mangroves undergo the second bridge construction during which important mangrove areas are being destroyed. However, this urbanization transformed hectares of forest characterised by mature stands of mangrove trees such as *Rhizophora* spp. and *Avicennia germinans* into highly degraded areas with a dramatic change in botanical assemblages (Nfotabong-Atheull et al. 2011).

Douala has a coastal nature, with the presence of water and mangroves, especially the river Wouri estuary. It is common to find dwellings surrounded by scanty or permanent water. Much of the city is less planned and is not built sustainably: less than 8% of the total area is occupied by condominium, multi-storey, villa and single storey, whereas mixed construction has a surface area of 23.5% and mud/wood construction, 20.4% (CLUVA 2010). This indicates a very poor population and hence a high pressure on natural resources and vegetation. Plantations, parks, and agriculture cover only a little part of the area. In the face of the rapid urban expansion for the past 20 years, it is certain that the demand for sand, soils and scoria would remain elastic. The profitability and others facilities offered by the Douala city favored this activity and induced the increment of quarries.

Urbanization is one of the most unfavorable factors to the conservation and evolution of terrestrial ecosystems in emerging or developing countries (Fig. 3.12). The Cameroon coast contains four major cities with mangrove stands border agglomerations from Kribi to Limbe. Mangroves of Kribi were heavily damaged by the installation of modern buildings at the seaside (Nfotabong-Atheull 2011). The construction of tourist complexes after the realization of the asphalt road that connects Kribi to Edea have spared no specimen of mangroves (Din 2001). The development of the city of Tiko destroyed mangrove mainly in the old port that was certainly attracted people in the area. The installation of new populations favored the destruction of a major band of mangrove.

The establishment of roads inside mangroves led to an ecological fragmentation and isolation of two sides of mangroves that can no more exchange materials between them. The general aspect of the vegetation (composition and structure) corresponds to a senescent stand where swamp forest species gradually invade the site. Mangrove ecosystems could survive after fragmentation if the derivative forests are regularly watered by daily tides. The zonation and the progressive series change and affect deeply the structure of the forest but the composition will remain unchanged even if the structure of trees is also affected. Species like *Nypa fruticans* take advantage of such phenomenon to occupy more space.

Although mangroves contribute considerably to the social and economic well-being of the Cameroon coastal inhabitants, their total surface area has decreased by 30% in 20 years (Spalding et al. 2010), mainly due to rapid and uncontrolled urbanization around Douala city (Din et al. 2002; Ellison and Zouh 2012; Nfotabong-Atheull et al. 2013).

3.4.5 Wastes

Wastes and wastewater discharged into nearby mangrove forest, marshes and rivers can finally get into the mangroves ecosystem due to rainfalls, currents and tide movements. Direct discharges into mangroves are frequently observed in the Wouri estuarine mangrove. The mangrove areas are daily transformed as solid and liquid waste disposals accepted by the Douala urban council without any restriction

Fig. 3.12 Anarchic urbanization destroying mangrove ecosystems. (**a**) Electrification project following population settlement in mangrove degraded areas; (**b**) building inside mangrove area; (**c**) state project converting mangrove ecosystem; (**d**) fragmentation of mangrove forest resulting from a road opened

Fig. 3.12 (continued)

(Fig. 3.13). Tankers poured out liquid wastes collected from private cesspools along the city directly in the mangrove areas between Youpwe and Bois Des Singes. The Douala urban council lay a tax on this hazardous activity.

In the SW part of the town (Mambanda), a sawmill had poured for several decades solid wastes into the mangrove forests and had taken advantage of the progressive degradation of the forest to get a considerable free space. Many other

Fig. 3.13 Deposit of solid (**a**) and liquid (**b**) wastes in mangrove areas

factories and population discharge their waste directly into the rivers of the Cameroon estuary. Mangroves of the Wouri estuary have progressively become potential dumps for solid materials of which the low decomposition will cause the forest depletion associated with the intoxication of the food chain.

3.4.6 Petroleum Activities

Mangrove forests provide generally a variety of goods and services (Dahdouh-Guebas 2001; Walters et al. 2008). Oil spills seeping into coastal waters and rivers, covering exposed roots of mangroves and airy. It is difficult or impossible to respiratory plants lenticels to perform their essential functions when covered in oil, so they are slowly and progressively asphyxiated. The massive successive deaths of mangroves is a common phenomenon afflicting the mangrove areas where oil exploitation is practiced. All petroleum activities are source of risk. Due to the fact that oil spills often occur in remote areas, a large number of frequent accidents could go unnoticed for long periods of time and are not cleaned effectively and timely manner. According to Din (2001) such situations may occur in the mangrove of the Rio del Rey estuary as oil activities in this area are free from any control on their environmental impact.

Douala is one of the major shipping ports in the Guinea Gulf that serves the entire central Africa and refuels oil tankers to export locally extracted oil, another significant anthropogenic impact on the Wouri river estuary mangroves (Alemagi 2007; Duke 2016; Price et al. 2000; Van De Walle 1989). Many hazards from petroleum activities have been encountered in all mangrove areas of Cameroon (Fig. 3.14). Drilling activities destroyed many hectares of mangroves forest near Douala. A serious oil spill from the Limbe refinery had damaged all mangrove stands along the Atlantic Ocean. Seismic lines are responsible of mangrove depletion in the two mains mangrove stands of the country.

Non peri-urban mangroves located in the estuary of Cameroon, the mouth of the river Nyong and Kribi will face in the future to disturbance from exploration (seismic survey to identify potential petroleum reserves) and oil exploitation (Nfotabong-Atheull 2011). Devegetation of these intertidal forests resulting from seismic delineation leave bare soil may be eroded by wave movements (Osuji et al. 2010). The disruption of the structure of mangroves will be inevitable since the seismic exploration phase (cable routing) often require cutting trees up (Osuji et al. 2007). As has been shown in Nigeria, the recovery of disturbed areas will take about 3 years (Aston-Jones 1988).

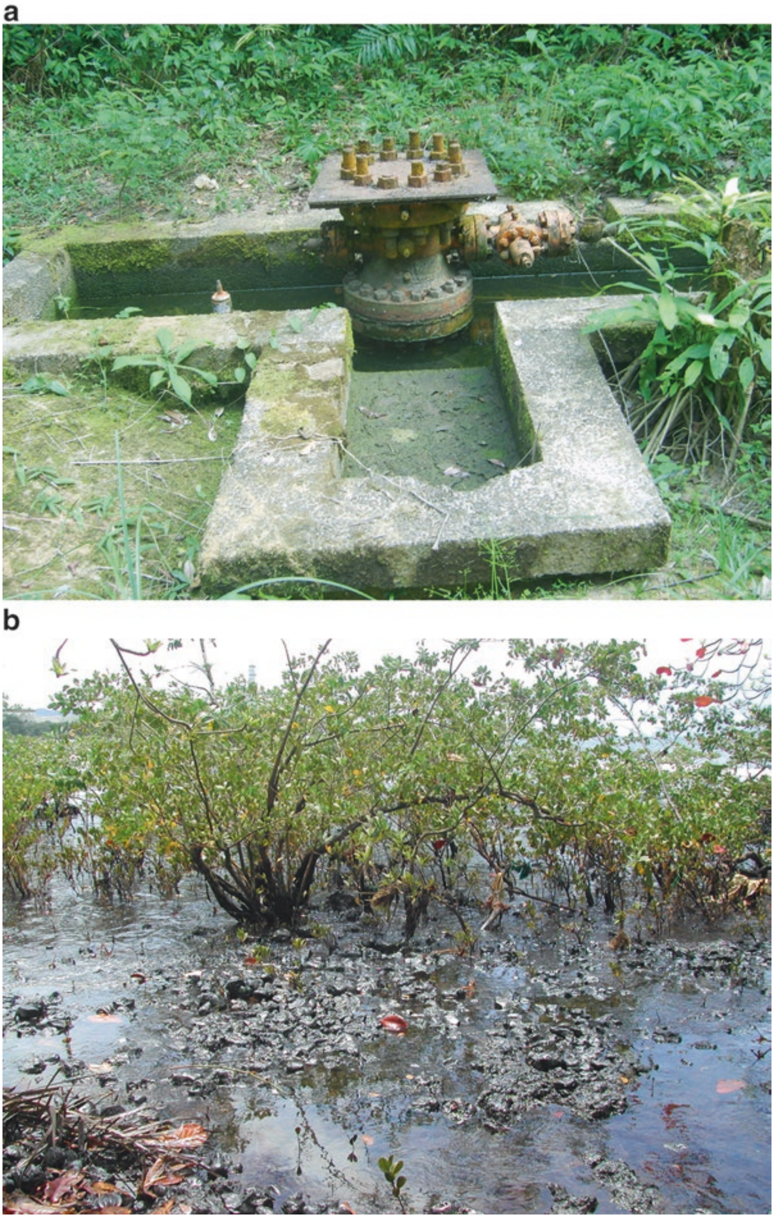

Fig. 3.14 Effects of petroleum activities on mangrove ecosystem. (**a**) Abandoned well inside mangrove area; (**b**) mangrove degradation due to oil spill; (**c**) mangrove depletion after accumulation of wastes from drilling operations

c

Fig. 3.14 (continued)

3.5 Evolution of Douala City and Mangrove Degradation

3.5.1 Effects of State Projects

The implementation of projects for the urbanization of the city of Douala is one of the worst factors to mangrove conservation of the Wouri estuary river. The Douala city's urban plan had foreseen in the 1990s, the extension of the present "Boulevard Général Leclerc" to Bonamoussadi (northern part of the city). Its implementation should involve the disappearance of all coastal mangrove patches on the left bank of the Wouri river. In the same project, it provides a bridge that connects Bonamoussadi to Bonendale through Bonamatoumbè and Djebalè. That project combined with the "Sawa Beach project" will be an environmental disaster for the mangroves of the Wouri river estuary (Din 2001). The above projects are actually being executed. The predictions seem to be exact and the disappearance of mangrove stands are effective (Fig. 3.15). The construction of roads alone will cause a sharp reduction in mangrove areas. Building the bridges will result in more reduction surfaces, the deviation of the supply channels, blocking channels that feed the mangrove substrate and the installation of population. The construction of road infrastructure has an impact on the general aspect of the vegetation and structure of tree characteristics that match senescent stands where swamp forest species invade sites.

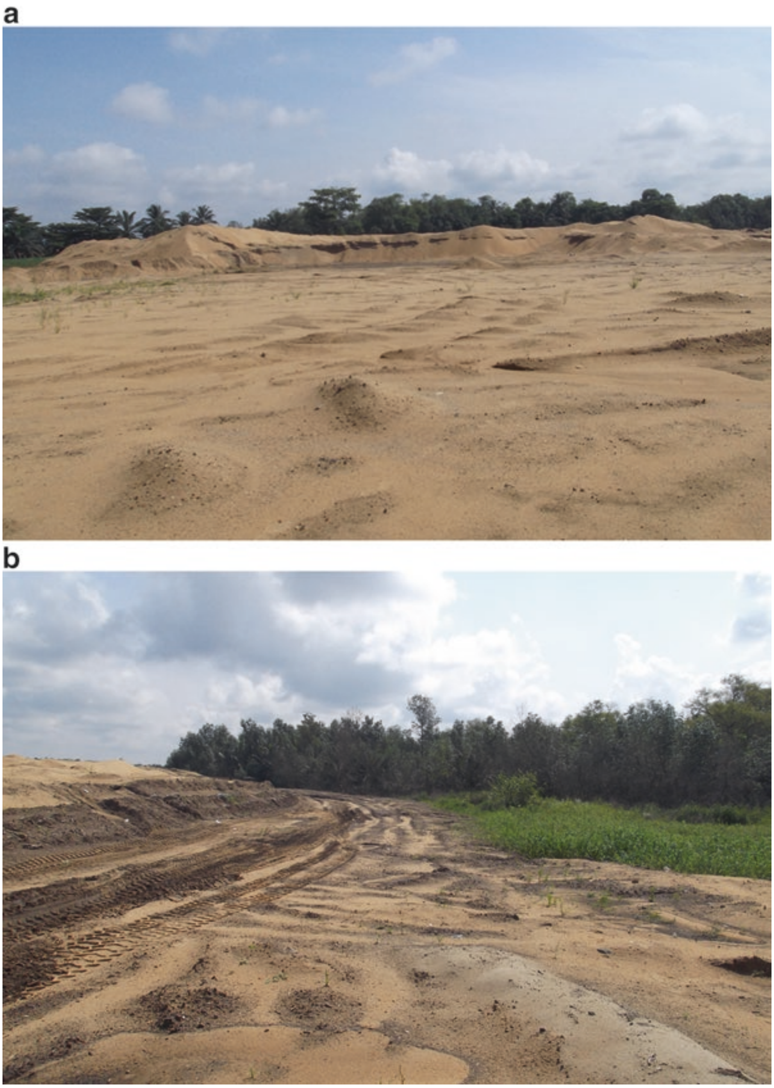

Fig. 3.15 Effects of the Wouri bridge rehabilitation on the neighboring mangrove ecosystems. (**a**) Bending sand on mangrove forests; (**b**) road opened inside mangrove area; (**c**) installation of equipment and live camps after mangrove area depletion; (**d**) extension of destruction and supply of solid materials; (**e**) progress of *Avicennia* band damaging; (**f**) total drainage of soil and trees which means mangrove disappearance

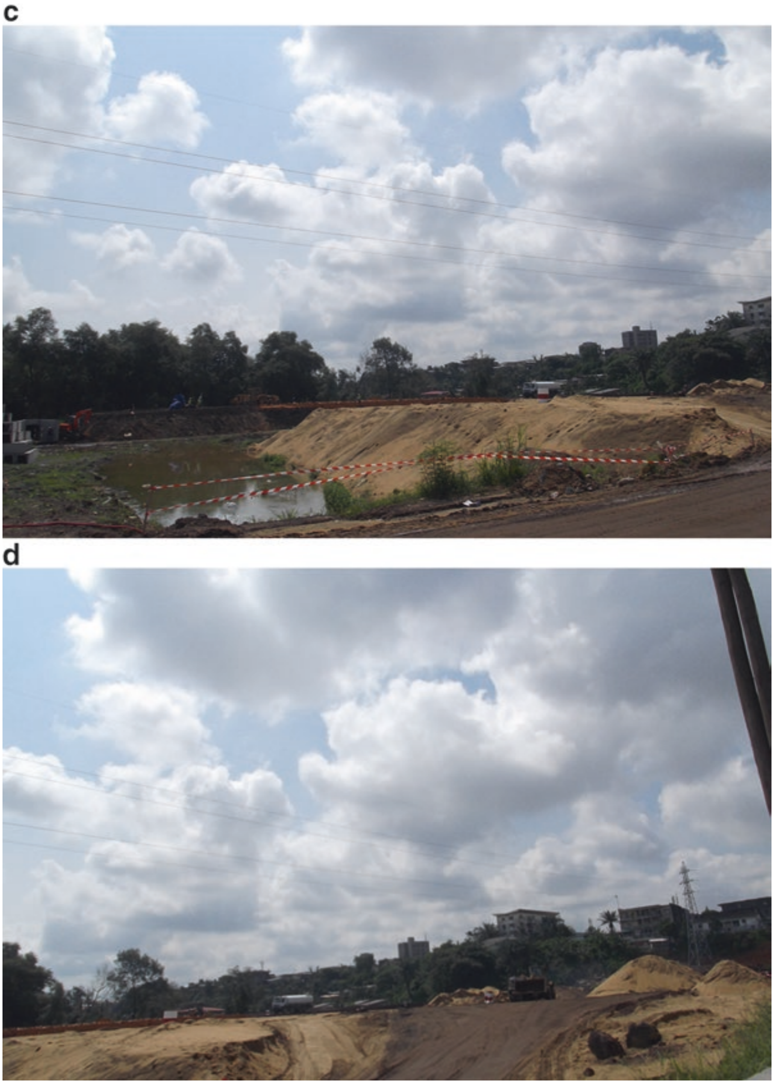

Fig. 3.15 (continued)

Fig. 3.5 (continued)

The construction of the road that connects Bonaberi to Bekoko caused the breakdown of many mangrove stands at the locality of Yapaki. Along this axis, shrubs of all mangroves characteristics species are frequently observed. The rehabilitation of the Wouri Bridge area in the 1980s, the creation and expansion of the port area and the creation of new residential areas including Mambanda (Bonaberi), Deido, Bonanloka, significantly reduced the surfaces of mangroves. This loss of vegetation cover of mangroves has ecological, economic and social effects.

The city's development projects have caused the loss of biodiversity of the mangroves of the Wouri river estuary with the loss of species in the Mboussa Essengue area include *Cassipourea barteri* (Hook. f. ex Oliv.) N.E. Br., and a proliferation of *Nypa fruticans*. The latter species is experiencing exponential colonization of the areas. The completion of several state projects had heavily impacted the evolution of mangroves in the Wouri estuary river. Ultimately, these achievements certainly cause the disappearance of important mangrove areas.

3.5.2 Effects of Demographic Pressure

In addition to a high rate of natural increase, estimated at 29‰, Douala receives each year, according to estimates from the Urban Community, a minimum of 120,000 new inhabitants. So it is every year more than 200,000 people in addition to the population, an increase of nearly 7%.

This significant demographic pressure leads to uncontrolled land use and therefore to the appearance of vast squatter settlements in mangrove areas (Fig. 3.16) and in swampy areas at risk. These spontaneous settlements not geometrized, the almost non-existent social and health infrastructure are precarious living conditions. Dense populations living there in promiscuity exposed to any health risks resulting from urbanization deficit and aggravating themselves the environmental degradation especially of mangrove ecosystems.

The development of these areas begins with the clearing of mangrove and continues with the blocking of channels that feed more or less saline substrate. The latter action is very harmful to these mangroves formation because it causes a dryness that causes the substrate in addition to the physiological drought, natural or climatic drought. This means of conquering new spaces has been used in many localities of the city of Douala including Mboussa Essengue, Youpwe, Bois-des-Singes, Bobongo and Bonaberi (Fig. 3.16a).

When the water supply channels of the substrate are created, herbaceous plants quickly disappear as soon as the water environmental conditions become unfavorable. The area is gradually replaced by species swamp forests (*Alchornea cordifolia*, *Anthocleista vogelii*) and later herbaceous plants of mainland settled, marking the disappearance of mangroves (Din 2001).

3.5.3 Effects of Poverty

Like many other countries, Cameroon has experienced in the 1990s, a severe economic crisis that has resulted in numerous job losses and income for the people. This has not been a favorable factor for the development of mangroves. Helping economic calculations, it was easy to understand that the free surfaces such as mangroves were predilection sites since the cost of the development was below the purchase or lease

a

b

Fig. 3.16 Population pressures on Bonaberi and Douala mangroves with the construction of houses (**a**) and roads (**b**)

of a yet more appropriate field. Many people who hoped to find the Eldorado in the economic capital have in the rural exodus invests Douala. These people have acquired housing inside mangrove areas and live in dire poverty (Fig. 3.17a).

One consequence of the great crisis in Cameroon in the 1990s, is an increase in the solicitation of the mangroves of the Wouri river estuary. Thus, people who had lost their jobs have returned to the mangrove ecosystem that showed no stress and no protection. These people are converted in the extraction of sand, cutting and sell-

Fig. 3.17 Population settlements in dangerous health conditions (**a**) house constructed in swamp area; (**b**) collection of poles (*Rhizophora* and *Nypa fruticans*) for house building

ing mangroves firewood and timber, making charcoal, cutting poles for house construction (Fig. 3.17b). They have mostly invested their savings to optimize their new business with the acquisition of cutting equipment and a highly efficient logistics including saws motor and large canoes with outboard motors.

Health services and sanitation of the Douala City Council are not yet involved in the maintenance of populated areas near the mangrove. In reality, these areas are not included in the development plans and their populations, despite the fact that they pay taxes, are still considered marginal. All domestic waste is directed to mangroves and organic pollution by domestic waste is highly noticeable. In addition to household waste, there is also considerable amounts of fecal waste.

3.5.4 *Effects of Land Uses*

3.5.4.1 Effects on Mangrove Forest

Several anthropogenic factors (logging, anarchic urbanization, agriculture, industrial pollution, sand extraction) are responsible for a decrease in the mangrove cover. Despite mangrove forests in Cameroon being legally protected since 1996 (Frame-law n°96/012 relative to management of environment in Cameroon), there was an effective loss of mangrove forests in the peri-urban settings of Douala since four decades and possibly persisting beyond. Nfotabong-Atheull et al. (2013) have documented the effect of anthropogenic land use in the reduction of mangrove cover around the Wouri estuary both qualitatively and quantitatively. The overall accuracy of the land use/cover map of 2009 was above 90% with an overall Kappa index of 0.87.

A trend of decrease in mangrove area and increase in human settlements was observed between 1974 and 2009. In 1974, mangrove forests covered 51.89% (3.01 km^2), where as in 2003 it was 31.20% (1.81 km^2), indicating a decrease of 39.86% over the 29-year period (Table 3.2). In the 2009 photograph, mangroves represented 24.29% (1.41 km^2), a decrease of 22.10% to that of 2003. Between 2003 and 2009, the coverage of less disturbed mangrove forests decreased from 0.80 to 0.29 km^2 representing a decrease of 63.75% over the 6-year period.

In contrast, the rate of change in large disturbed mangrove extend after 2003 ranged from 55.80 to 79.43%, amounting to an increase of 10.89% between 2003 and 2009. In 1974, settlements made up 18.11% (1.05 km^2), whereas in 2009 they extended to 28.94% (1.68 km^2) with an increase of 60% over the 35-year period. However, the measured rate of mangrove decrease is twice as high as that estimated for tidal forest degradation at Mngazana estuary, Eastern Cape, South Africa (Rajkaran and Adams 2010), which amounted to ~21% (~32 ha) of mangrove loss since 1982 or to a decline of about 1 ha/year. Although none of the mangrove species present in Cameroon have been listed as threatened (Polidoro et al. 2010), populations are at risk from habitat loss (Table 3.4).

Since 2009, the introduced mangrove palm *Nypa fruticans* Thurnb. Wurmb. was found growing in large open areas and along the muddy river front. This species was also found in the field under the canopy of less degraded mangrove forests, places where it had not been possible to accurately delineate its distribution on the airborne imagery. The increase in areas occupied by water, road, agricultural land, sand quarry, wood market, and other vegetation types (mainly composed of *Annona glabra* L., *Drepanocarpus lunatus* GWF Meyer, *Paspalum vaginatum* Sw., *Anthocleista vogelii* Planch., *Sesuvium portulacastrum* L., and *Alchornea cordifolia* Müll. Arg.).

3.5.4.2 Effects on Mangrove Fauna

Though such decrease in mangrove faunal composition was recorded in the Littoral region, many interviewees linked it to the anthropogenic disturbances prevailing. Local people unanimously shared the opinion that trawler activities along the shore

Table 3.4 Land use/cover changes derived from 1974, 2003, and 2009 aerial photographs of Douala (Cameroon) peri-urban setting

Land use/cover	Area at 1974 (km^2)	Area at 1974 (%)	Area at 2003 (km^2)	Area at 2003 (%)	Area at 2009 (km^2)	Area at 2009 (%)	Change 1974–2003 (%)	Change 2003–2009 (%)	Total change 1974–2009 (%)
Mangroves	3.01	51.89	1.81	31.20	1.41	24.29	−39.86	−22.1	−53.16
Settlements	1.05	18.11	1.57	27.06	1.68	28.94	49.52	7	60
Agriculture	–	–	0.25	4.31	0.29	4.99	–	16	–
Other vegetation types	0.15	2.59	0.34	5.86	0.43	7.41	126.66	29.41	193.33
Water	0.17	2.93	0.33	5.69	0.43	7.41	94.11	30.3	152.94
Road	0.06	1.03	0.15	2.58	0.2	3.44	150	33.33	233.33
Sand quarry	–	–	0.01	0.17	0.01	0.17	–	0	–
Youpwe wood market	–	–	0.002	0.03	0.006	0.10	–	66.67	–
Airport	1.36	23	1.34	23	1.35	23	−1.47	0	0

Nfotabong-Atheull et al. (2013)

resulted in a decline in local fish catch inside the mangroves. This negative change was reinforced by the increased number of local fishermen. A decrease in the population of silurid, tilapia, mullets, shrimp, oyster and crab species, was probably related to changes (siltation, reduced water circulation, etc.) that occurred in the waterways.

Crab assemblage has shown a considerable variation in terms of species richness and abundance according to deforestation (Ngo-Massou et al. 2016). Abundances of *Chiromantes buettikoferi* De Man, 1883 (from 4.5 to 2.6% of individuals), *Metagrapsus curvatus* Herklots, 1951 (from 12 to 7.68% of indiviuals), *Sesarma* sp. (from 4.3 to 2.7% of individuals), *C. angolense* Brito Capello, 1864 (from 10.73 to 3.30% of specimens) and *Perisesarma alberti* Herklots, 1951 (from 16.61 to 6.42% of specimens) decreased. The number of species in Sesarmid crabs (from 10 to 8 species) and Gecarcinid crabs (from 3 to 1 species) fallen down. The importance of vegetation and channel distance on crab distribution has been described (Ngo-Massou et al. 2014). Vegetation is highly dominated by *Rhizophora* plant and that zone is the most diversified (18 crab species) which, two crab *Helice* sp. and *Maja squinado* Herbst, 1788 were strictly pledged. Therefore, the overexploitation of *Rhizophora* spp. lead the loss of these two indigenous crabs. Furthermore, *Cardisoma* spp. and *Uca tangeri* Eydoux, 1835 species are the most terrestrial crabs, because they live essentially close to back mangroves. With regards to anthropogenic activities, these terrestrial crabs are mainly threatened more than *Callinectes pallidus* Rochebrune, 1883 and *Portunus validus* Herklots, 1951, crabs found only near channels (marine crabs).

3.6 Conclusion

In spite of the existing laws and regulations in order to protect mangrove ecosystems in Cameroon, the rate of deforestation is significantly high in Douala periurban mangroves. The depletion issue from natural disaster must be considered as negligible in compare with anthropogenic activities. The fact that state projects toward mangrove areas did not especially show example of the importance of biodiversity protection, neighboring population profited from the authorities' laxity to accelerate the depletion mainly by building up to the channels and tributaries.

Considering in addition the demographic pressure in the city, always coupled with human poverty and associated here with a high level of incivism, the mangrove ecosystem will disappear in less than two decades if the authorities continued to mismanage the population settlement in coastal peri-urban areas.

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