Vegetation of Mangroves: Spatial and Temporal Pattern of its Dominant Populations in Futian National Nature Reserve

Li Zhenji (李振基), Zheng Wenjiao (郑文教), Yang Zhiwei (杨志伟), Lin Yiming (林益明), Lin Peng (林　鹏)
School of Life Sciences, Xiamen University, Xiamen 361005, *Fujian, China*

Abstract The community characteristics of mangroves in the Futian Nature Reserve, Shenzhen, China are given based on surveying of 33 quadrats in 4 transects which stretch from the higher tidal zone to the lower tidal zone. The results show that there are 6 community types in this area: *Kandelia candel* association, *Avicennia marina* association, *Aegiceras corniculatum* association, *Kandelia candel* + *Aegiceras corniculatum* association, *Aegiceras corniculatum* + *Kandelia candel* association and *Acanthus ilicifolius* association.*Ka ndelia candel*, *Aegiceras corniculatum* and *Avicennia marina* dominate the typical quadrats.*Ka ndelia candel* can be seen at almost all quadrats, *Aegiceras corniculatum* distributes mostly toward the estuary and the higher tidal zone, *Avicennia marina* distributes mostly toward the bay and the lower tidal zone, *Bruguiera gymnorrhiza* occasionally occurs toward the Estuary with one or several individuals, *Acanthus ilicifolius* was common toward the higher tidal zone, as an accompanying species, *Derris trifoliata* was common in many mature quadrats. Totally, 6 species of mangrove plants and 3 species of semi-mangrove plants appear in this research area. From the higher tidal zone to the lower tidal zone, the average diameter and basal area of mangrove trees increase gradually. According to the results, the *Avicennia marina* dominates in average diameter and basal area, and the *Aegiceras corniculatum* trees are on the contrary. From the transect 1 to the transect 4, the importance value of *Avicennia marina*, *Bruguiera gymnorrhiza* and *Kandelia candel* decreases, and *Aegic eras corniculatum* increases. In this area, the *Kandelia candel* population and *Aegiceras corniculatum* population are developing populations with many seedlings and saplings, but the *A vicennia marina* population is in a mature stage with few seedlings and not so many total individuals. According to this research, we suppose that *Aegiceras corniculatum* should be developed toward the estuary and the *Avicennia marina* association should be protected.

Keywords Vegetation analysis, *Kandelia candel*, *Avicennia marina*; *Aegiceras corniculatum*, Community, Population structure, Shenzhen

1 Introduction

Mangroves are the dominant intertidal ecosystems throughout the tropical and subtropical regions of the world and enter the subtropics as far north as Japan (32 ° N) and as far south as Victoria, Australia (38 ° 54.8 ′ S)[1, 2]. The climate and landform characteristics of a coastal region together with local ecological processes control the basic properties of mangrove wetlands[3, 4]. Lower scale factors such as microtopography and tidal hydrology can influence the zonation of mangroves from

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shoreline to the farther inland locations forming ecological types of mangrove wetlands[1, 5]. Twilley (1995, 1997) suggested that a gradient in the geophysical processes of a coastal region together with local ecological factors will determine the diverse patterns of energy flow and biogeochemistry of mangrove wetlands[4, 6]. Since mangroves are considered naturally stressed ecosystems[7], their structural complexity is shaped by many cyclic events, so they usually reach maturity in 20~30 yr[8] an d can also be considered as systems with multiple equilibrium states[9, 10]. Natural disturbances at a smaller spatial scale can also influence mangrove species zonation and succession[8, 11, 12]. Sometimes they can also shape landscape patterns of vegetation distribution at larger spatial and temporal scales[13, 14].

The restoration rate of mangroves from a disturbance depends on the particular species that survive the disturbance[15]. Thus initial conditions of mangroves structure and rates of sapling recruitment are important for mangroves development[16]. Differences in mortality and growth rates in several areas across the landscape in mangrove forests will also have a strong influence on the spatial distribution of mangrove species since competition for resources among mangrove species is expected to affect regeneration dynamics[17~19].

It is assumed that mangroves are net exporters of organic matter that provide detritus for the higher trophic levels[2, 20~23]. Here, the mangrove plants not only stabilize the estuary ecosystem, keep the species diversity, but also provide a habitat for many birds, insects, fishes, invertebrates and microbes in this area and support a complex food web. Mangroves are also important to the ubsistence economics all the world, providing firewood, building materials, and other wood products, as well as ecosystem services such as water quality maintenance, storm wave protection, fish habitat, and ecotourism activities[23~ 26].With increasing population pressure, these forests are now extensively exploited[27].

In this paper, based on surveying of 33 quadrats in 4 transects which stretch from the higher tidal zone to the lower tidal zone the mangroves in Futian Nature Reserve have been studied. By comparing the vegetations of mangroves and the spatial and temporal pattern of the dominant mangrove populations, we try to provide data for management, conservation and restoration of mangroves and other biodiversity in this region.

2 Study site and methods

2.1 Study area

The study area is located in the Futian Mangrove Nature Reserve (22°32′N, 114°03′E), about 8 km south of Shenzhen, Southern China. The wetland of Shenzhen River, its estuary, and Shenzhen Bay is an internationally important wetland. The Futian National Nature Reserve is one of its core parts as well as the Mai Po Nature Reserve of Hong Kong which has recently been included in the List of Wetlands of International Importance under the RAMSAR Convention (Convention on Wetlands of International Importance Especially as Habitat for Water Birds). This area and its surrounding environment provide a habitat for birds to live and get food in. There are 189 species of birds, including waterfowl, migratory birds and raptors in this area[28, 29]. Because more and more coastal bird habitats have been destroyed, some species are in crisis throughout the world, here the mangroves has become an important wetland for migratory birds to live and get food in. It is located in southern subtropical evergreen broadleaved forest zone and stretches 11 km from the Shenzhen Bay to

Shenzhen River, and covers an area of 304 ha. And the adjacent land is a mosaic of disturbed pond and cultivated land. The predominant soil type in mangroves is muddy earth.

The climate of this area is a hot, oceanic monsoon one. The mean annual temperature is 22℃ and 0.2℃ (minimum) and 38.7℃ (maximum), and the mean annual precipitation is 1 927 mm, which occurs principally during May to September, and the mean annual relatively humidity 79%. The mean monthly radiation is 450j • m, with the highest radiation in August (590 j /m^2) and the lowest in February (322 j / m^2). The mean duration of light is 6.1 h / d, with the minimum and maximum hours of radiation occurring in February (4.2 h / d) and August (7.8 h / d) respectively. The mangrove forest is inundated by incoming tide twice a day and the spring tidal range is about 2.8 m.

The soil ranges from sandy clays in the Bay to silty clays in the estuary, the clays were deep and structureless, and the salinity of surface clays (14.48 ‰) and pH value (5.30) were lower than that of the deeper layer clays (18.21 ‰ ~ 19.28 ‰ and 6.58 ~ 7.14) (Tab. 1).

Tab. 1 Soil physicochemical properties of mangroves stand in Futian Nature Reserve[30]

Depth (cm)	pH Value	Salinit (‰)	Volume Weight (g/cm^3)	Concentration of elements (% dw)			
				K	Na	Ca	Mg
0~30	5.30	14.48	0.460	1.25	0.70	0.11	0.94
30~60	6.58	18.21	0.618	1.17	0.68	0.11	0.86
60~90	7.14	19.28	0.640	1.05	0.55	0.10	0.70

2. 2 Measurements

Ground survey has been undertaken from February to March and four zonary transects (T1, T2, T3, T4) which are 10 m wide and perpendicular to the coastline (from the higher tidal zone to the lower tidal zone) established. Transect T1 is near the Shenzhen Bay end, Transect T4 near the Shenzhen Estuary end. Transect T3 across the widest mangroves swamp which is about 285 m in width (Fig. 1).Along each transect, 10 m by 10 m quadrat per 20 meter is delimited and exhaustively

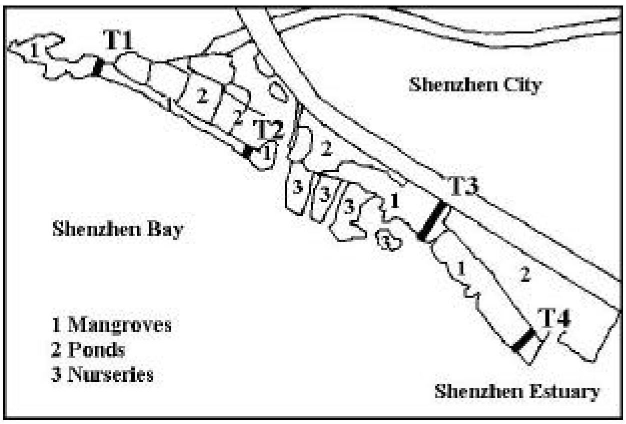


Fig. 1 Location of 4 Tranaects in Futian Mangrove Nature Reserve

sampled. In each quadrat along the transects, the quadrat method is used to estimate structural parameters, height, diameter at breast height (DBH; the minimum sampling diameter is 2.5 cm), density, dominance, frequency, and the importance value (IV) for all tree species is recorded[31, 32]. The abundance is the numbers of the species in the same quadrat or a transect, frequency is the probability of finding the species in the same quadrat or a transect, dominance is the total basal area per species, and basal area is the cross-sectional area of the tree at a point 1.3 m above ground. Then the three values of relative abundance (RA), relative frequency (RF) and relative dominance (RD) are summed to obtain for each species its importance value (IV)[33]. Trees, which branch below the breast height, are treated as several stems, and the parameter of each branch is recorded. For saplings (DBH < 2.5 cm) or shrubs or seedlings, only the individual numbers are recorded.

3 Results

3.1 Species distribution

According to the survey on this area, there are 6 mangrove species, 4 semi-mangrove species and 1 accompanying species in the Futian Nature Reserve. Mangrove species includes *Kandelia candel* (L.) Dance (Rhizophoraceae), *Bruguiera gymnorrhiza* (L.) Savigny (Rhizophoraceae), *Aegiceras corniculatum* (L.) Blanco. (Mysinaceae), *Avicennia marina* (Forsk.) Vierh (Verbenaceae), *Acanthus ilicifolius* Linn. (Acanthaceae) and *Excoecaria agallocha* Linn. (Euphorbiaceae). Semi-mangrove species are *Acrostichum aureum* Linn., *Thespesia populnea* (L.) Engl. and *Pluchea indica* (L.) Less., and *Derris trifoliata* (accompanying species) is a common liana species in mature community.

The species distribution along transects is shown in Figure 2. All the 4 transects have a clear zonation pattern. Five mangrove species could be seen in all the 4 transects, and the accompanying species *Derri s trifoliata* has been surveyed except in T4. *Kandelia candel* dominates the quadrats toward the higher tidal zone, where there are some *Aegiceras corniculatum*, *Acanthus ilicifolius*, *Derris trifoliata*, and a few *Bruguiera gymnorrhiza*. In the quadrats of the middle tidal zone, 5 mangrove species are found frequently. And in the lower tidal zone, only *Avicennia marina*, *Kandelia candel* and *Aegicera s corniculatum* can be found. *Acanthus ilicifolius* is a lower shrub and mainly grows in the mud bank of creek along the seashore. *Acrostichum aureum* has been only seen toward the higher tidal zone, *The spesia populnea* and *Pluchea indica* which have been recorded in previous researches[34] are not found on the 4 transects in this survey.

From the estuary to the bay along the seashore we could also find a different distribution pattern, *Aegiceras corniculatum* mainly distributes in the estuary, and sometimes formes a pure association. But at the bay, we almost cannot find it. In contrast, in T4, T3, there are only a few individuals of *Avicennia marina*. The *Avicennia marina* becomes more and more common from the estuary to the bay, then in T1, it forms pure association, and its relative density reaches 100%. *Kandelia candel* is common from the estuary to the bay, but *Bruguiera gymnorrhiza* is rare throughout this area. *Acanthu s ilicifolius*is common toward the higher tidal zone at the 4 transects, but *Derris trifoliate* could not be found in T1.

3.2 Density of mangrove plants

Tree density (individuals per ha) varies in different communities. It is lowest in *Avicennia marina* association (only 3 200~10 000/ha) in the quadrat 5 to the quadrat 6 in transect 1. It is intermediate condition (6 400~ 20 000/ha) in *Kandelia candel* association in all transects. It is nearly 30 000/ha in *Aegiceras corniculatum* association in the quadrat 6 in T4. The DBH of *Acanthus ilicifolius* is smaller than 2 cm, but its density can reach 200 000/ha.

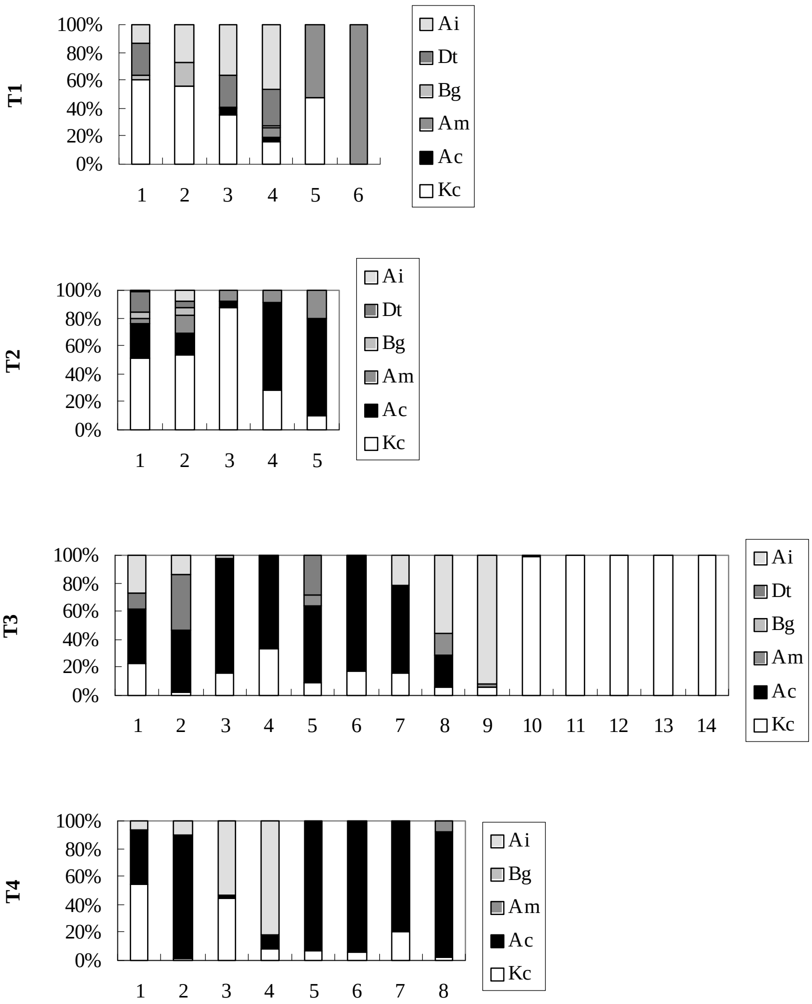


Fig. 2 Distribution of mangrove plants along transects (Percent of density)

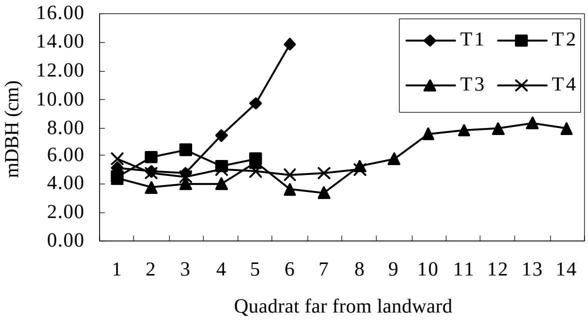
Kc: *Kandelia candel*; Ac: *Aegiceras corniculatum*; Am: *Avicennia marina*; Bg: *Bruguiera gymnorrhiza*; Dt: *Derris trifoliata*; Ai: *Acanthus ilicifolius*

3.3 Mean stand diameter and total basal area

As indicated in Figure 3, the mDBH of all transects increases in the mass from the higher tidal zone to the lower tidal zone. In T1, the mDBH decreases smoothly from quadrat 1 to quadrat 3, then increases rapidly from 4.83 cm in quadrat 3 to the peak 13.81 cm in quadrat 7. It is due to the big *Avicennia marina* trees. In T2, the mDBH of stand changes smoothly between 4.49 cm to 6.42 cm, with a little lower in quadrat 1 (4.49 cm) and quadrat 4 (5.26 cm) due to too many *Aegiceras corniculatum* tree

s. The mDBH of stand in T3 increases in the mass from the higher tidal zone to the lower tidal zone, and it reaches a second peak (5.50 cm) in quadrat 5 for a narrow zone which stretches from T1 and makes up of *Avicennia marina* mainly, followed by two lower mDBHs (3.67 cm and 3.38 cm) due to many small *Kandelia candel* and *Aegiceras corniculatum* trees. The mDBH of stand in T4 is almost the same (4.92) except in quadrat 1 (5.78) where the stand is composed of *Kandelia candel* mainly.

As indicated in Figure 3, the total basal area in different quadrats varies greatly, for its value depends on the dominant species remarkably and the number of individuals in a quadrat. For example, the total basal area of quadrat 6 in T1 reaches the peak 1 213.80 cm^2 due to mature *Avicennia marina* tree and is bigger than the others. Sometimes the total basal diameter of *Aegiceras corniculatum* and *Kandelia candel* associations is small due to few trees in the quadrat.



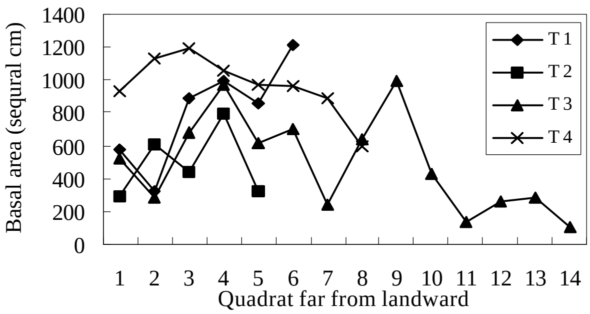


Fig. 3 Change of mean DBH and basal area (cm^2) from the higher tidal zone to the lower tidal zone in 4 transects

3.4 Importance value of trees in transect

The importance value is an all-around parameter to consider the importance of a species in a community[32, 35]. Here we use it to consider the importance of four species in different transects. As indicated in Figure 4, the importance value (IV) of *Kandelia candel* is the biggest (T1: 159.00; T2: 132.55; T3: 163.30) except in transect 4. The IV of *Avicennia marina* is inferior to *Kandelia candel* i n transect 1, and it becomes less and less from the Shenzhen Bay to the Shenzhen estuary. But *Aegicer as corniculatum* behaves the contrary way, it has a smaller IV in transect 1, then its IV becomes higher and higher, to the biggest one (176.1) in transect 4 located in the Shenzhen estuary. The IV of *Avicennia marina* is evidently in negative correlation with that of *Aegiceras corniculatum,* and the correlation formula is: $y = -1.6383x + 180.38$, $r = -0.9627$. In all the 4 transects, *Bruguiera gymnorrhiza* has the smallest IV.

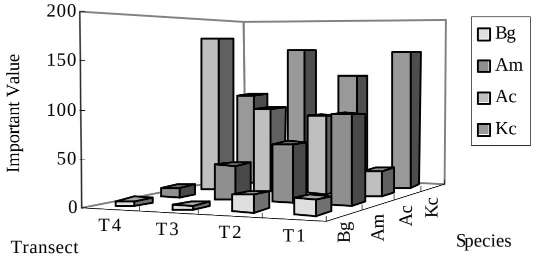


Fig. 4 Importance Value (IV) of 4 tree mangrove species in different transects
Kc: *Kandelia candel*; Ac: *Aegiceras corniculatum*; Am: *Avicennia marina*; Bg: *Bruguiera gymnorrhiza*

3.5 Population structure

Considering 3 dominant populations in this area (Fig. 5), we can find that *Avicennia marina* population has few seedlings and not so many total individuals, and we think it is in a mature stage.

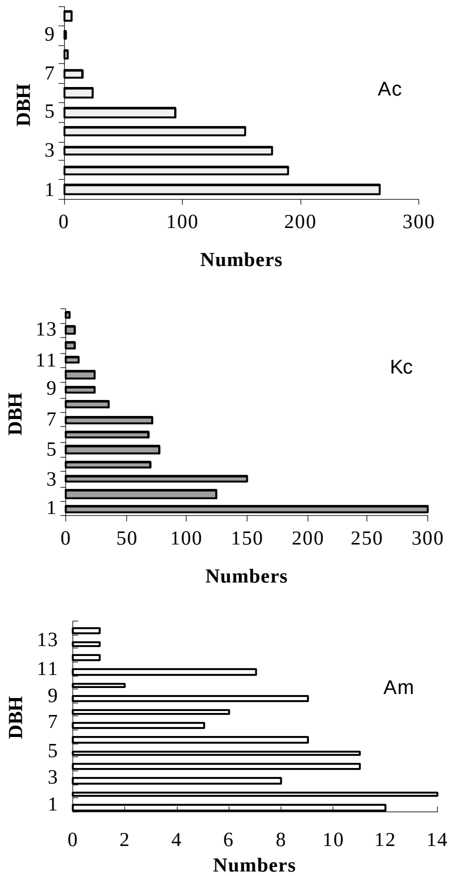


Fig. 5 The DBH structure of *Avicenia marina* (Am), *Kandelia candel* (Kc) and *Aegiceras corniculatum* (Ac) populations

Kandelia candel population and *Aegiceras corniculatum* population are developing populations with many seedlings and saplings, Here the *Kandelia candel* population is a typical developing population. As plants grow older, fewer and fewer trees could be found. *Aegiceras corniculatum* is a shrub-like plant, so the DBH of most individuals is below 5 cm.

3.6 Survival curve of three main mangrove trees

Consider the survival curve of 3 dominant populations in this area (Fig. 6). The results show that the percentage of adults decreases with the mean DBH, the survival curve of *Kandelia candel* population and *Aegiceras corniculatum* population fits the Deevey type III with a pattern of high juvenile and low adult mortality, but that of *Avicennia marina* population fits the Deevey type II with a constant death risk throughout[36].

3.7 Vegetation of mangroves

After thorough survey and analysis, the mangroves in the Futian Nature Reserve can be divided into six community types:*Kandelia candel* association, *Avicennia marina* association, *Aegiceras corniculatum* association, *Kandelia candel* + *Aegiceras corniculatum* association, *Aegiceras corniculatum* + *Kandelia candel* association and *Acanthus ilicifolius* association.

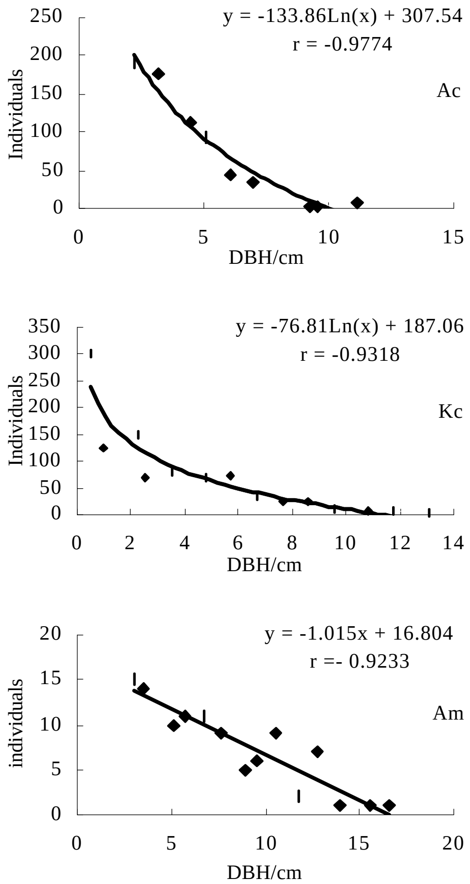


Fig. 6 The survival curve of *Aegiceras corniculatum* (Ac), *Kandelia candel* (Kc) and *Avicenia marina* (Am) population

(1) *Kandelia candel* association: *Kandelia candel* association exists in all the four transects. Sampling one typical quadrat to represent this association from each transect, the statistical result is shown in Table 2. This association is dominated by *Kandelia candel* absolutely with high importance value (IV = 198.7), occasionally with several *Aegiceras corniculatum* and *Avicennia marina* or *Bruguiera gymnorrhiza* in the quadrat. Saplings and seedlings of *Kandelia candel* are abundant. In addition there are many individuals of *Acanthus ilicifolius* in the shrub layer. Coverage of this association ranges from 90% to 100%. In some quadrats, *Derris trifoliata* (height 4.5 ~ 5.0 m) accompanies.

Tab. 2 Results of quadrats analysis for *Kandelia candel* association in Futian Nature Reserve (5×5 m^2, ×4 quadrats)

Spp.	No.	Occ.	DBH (cm^2)	RA (%)	RF (%)	RD (%)	IV	Rank
Kc	110(47)*	4	28 373	79.7	36.4	82.6	198.7	1
Ac	12(5)	4	1 968	8.7	36.4	5.7	50.8	2
Am	13	1	3 702	9.4	9.0	10.8	29.2	3
Bg	3	2	302	2.2	18.2	0.9	21.3	4
Ai	596	3						

*Brackets indicate seedling numbers. The follow tables were the same.

(2) *Avicennia marina* association: *Avicennia marina* association grows well toward the seaside of transect 1 and transect 2, and also appears in the central section of transect 3. Surveying four quadrats, the results are shown in Table 3. Canopy of this association is dominated by trees of *Avicennia marina*, accompanied by a few trees of *Kandelia candel* and *Aegiceras corniculatum*. Under the canopy there are many seedlings of *Aegiceras corniculatum* and *Kandelia candel*, but no seedlings of *Avicennia marina*. As viewed from the succession of the community, the *Avicennia marina* association may be replaced by *Kandelia candel* association or *Kandelia candel* + *Aegiceras corniculatum* association sometime later. The coverage of the community is over 80% and the tree is only 3.5 ~ 4.5 m in height.

Tab. 3 Results of quadrats analysis for *Avicennia marina* association in the Futian Nature Reserve (5×5 m^2, ×4 quadrats)

Spp.	No.	Occ.	DBH (cm^2)	RA (%)	RF (%)	RD (%)	IV	Rank
Am	49	4	32 583	80.3	44.5	96.0	220.8	1
Kc	7(12)	3	970	11.5	33.3	2.9	47.7	2
Ac	5(39)	2	377	8.2	22.2	1.1	31.5	3
Ai	72	1						

(3) *Aegiceras corniculatum* association: *Aegiceras corniculatum* association can only be seen in the transects 3 and 4. Sampling four quadrats, the results show that the association is dominated by *Aegiceras corniculatum* with more individuals, and sub-dominated by *Kandelia candel.* In this association we can hardly find *Avicennia marina* and *Bruguiera gymnorrhiza*. The association regenerates very well for the *Aegiceras corniculatum* and *Kandelia candel* populations appearing in a pyramidal age structure. In addition, a few of *Derris trifoliata* and *Acanthus ilicifolius* appear in the quadrat toward land. The association height is 2.5 ~ 4.5 m (Tab. 4).

Tab. 4 Results of quadrat analysis for *Aegiceras corniculatum* association in the Futian Nature Reserve (5×5 m², ×4 quadrats)

Spp.	No.	Occ.	DBH (cm²)	RA (%)	RF (%)	RD (%)	IV	Rank
Ac	142(28)	4	40 447	88.2	50	84.2	222.4	1
Kc	19(2)	4	7 585	11.8	50	15.8	77.6	2
Ai	37	2						
Dt	36	1						

(4) *Kandelia candel* +*Aegiceras corniculatum* association: This association is distributed in the transects 2, 3 and 4. The results show that the relative dominance of *Kandelia candel* is almost 3 times larger than that of *Aegiceras corniculatum* in this association, but relative abundance of the two species is almost the same. According to the results of investigation, there are so many saplings and seedlings in the forest that the association regenerates well. *Bruguiera gymnorrhiza* could be found occasionally. We can also find some *Acanthus ilicifolius* and *Derris trifoliata* in this association. Canopy of this community is so prosperous that the coverage is up to nearly 100% (Tab. 5).

Tab. 5 Results of quadrats analysis for *Kandelia candel* + *Aegiceras corniculatum* association (5×5 m², ×4 quadrats)

Spp.	No.	Occ.	DBH (cm²)	RA (%)	RF (%)	RD (%)	IV	Rank
Kc	53(43)	4	15 490	48.6	44.5	75.0	168.1	1
Ac	55(76)	4	4 808	50.5	44.5	23.3	118.3	2
Bg	1(2)	1	345	0.9	11.0	1.7	13.6	3
Ai	50	2						
Dt	24	2						

(5) *Aegiceras corniculatum* + *Kandelia candel* association: The association distributes in the transects 2, 3 and 4. The results are shown in Table 6. This community is similar to the former one. In this association, there are so many trees of *Aegiceras corniculatum* that its relative abundance (RA) is 3 times that of *Kandelia candel*, and the importance value of *Aegiceras corniculatum* is as high as 161.1. There are also a large number of individuals of *Acanthus ilicifolius* and a few of *Avicen nia marina* and *Bruguiera gymnorrhiza*.

Tab. 6 Results of quadrats analysis for *Aegiceras corniculatum* + *Kandelia candel* association (5×5 m², ×4 quadrats)

Spp.	No.	Occ.	DBH (cm²)	RA (%)	RF (%)	RD (%)	IV	Rank
Ac	138(52)	4	20 147	72.6	36.4	52.1	161.1	1
Kc	46(15)	4	17 079	24.2	36.4	44.1	104.7	2
Am	4	2	1 122	2.1	18.2	2.9	23.2	3
Bg	2(1)	1	339	1.1	9.0	0.9	11.0	4
Ai	253	1						

(6) ***Acanthus ilicifolius*** **small community:** *Acanthus ilicifolius* grows vigorously in the mud beach of creek. It was beginning to flower when we surveyed the area. It is a small community surrounded by *Panicum repens* and *Cynodon dactylon, etc*., with a height of 90 cm, and a density of 10 ind./m^2.

4 Discussion

4.1 Distribution of vegetation

Investigation and analysis of transects show that the mangroves present a zonation from the higher tidal zone to the lower tidal zone and from the estuary to the bay. In the longest transect-T3 (295 m long), there are many narrow ecotones. And the middle zone is dominated by *Avicennia marina* association for historical reasons. Lugo (1980) claimed that mangrove forests usually have sharp ecotones with adjacent ecosystems because the saline condition of the mangroves habitat is tidally and topographically determined[8]. Wherever the tide transports the saltwater inland, the mangroves will colonize available sediments. But slight topographic changes (in centimeters) can create a sharp ecotone where saline and tidal conditions end. Depending on the resulting hydrology or edaphic conditions, the adjacent ecosystem can be a freshwater wetland, a saline flat, a terrestrial ecosystem, or any combination of these. The transition from mangrove to non-mangrove habitats can be sharp as indicated or gradual, where mangroves become less and less important as the salinity and tidal regime change away from those that delimit the range of mangroves growth and survival. T1 and T2 exhibit a clear zonation pattern, where the density of trees is lower, but the mDBH of trees higher. The results show that the woodland has been protected for a long time. T4 is characterized by an early successional state of community and habitat: the distribution of species alters gradually, with higher tree density, lower mDBH and fewer species. It shows that the mangrove associations, which distribute mainly in the Shenzhen estuary, are formed lately. The research on the habitat of mangroves shows that *Aegiceras corniculatum* grows on the beach where the topsoil is spongy and deep, and *Avicennia marina* can grow in the sandy soil of beach[37]. This pattern reveals the heterogeneity of microtopography and hydrological features. It is a basis of biodiversity in this region.

4.2 Components of mangroves

According to the investigation on this area, there are 6 species of mangrove plants and 3 species of semi-mangrove plants in the Futian Nature Reserve. It seems that the mangroves are poor in species richness. Actually, it is all the same throughout the world. Lugo *et al.* (1988) proposed that fewer species are normally found in freshwater forested wetlands[38]. Values in these forests range from 1 to 23 species per hectare with averages of 8.3 and 6 species per hectare for riverine and basin freshwater wetlands, respectively. Mangroves are even more species-poor and in fact are among the most species-poor forest ecosystems in the tropics. Later Jansen (1985) found that mangroves often contain no understory plants[39], we can also encounter this situation in this area or in northern distribution range of mangroves in China[23]. Why? It may be due to the fact that its habitat conditions in the mangrove stands make it extremely difficult for non-halophytic and non-wetland plants to grow and reproduce. Even so, the mangroves hold more and more benthic animals and birds[29, 40]. Steinke *et al.* (1990) found the leaves of *Avicennia marina* and *Bruguiera gymnorrhiza* harbouring 20 ~ 25 species of fungi[41]. Otherwise, as *Derris trifoliata* just could be seen in mature quadrats, we propose it as an indicator species for mangroves succeeding toward the terrestrial forest.

4.3 Development of mangroves

Investigation shows that there are few seedlings in the *Avicennia marina* association, and its survival curve fits the Deevey type II. As there are many *Derris trifoliate* in this association, it is indicated that this association has reached a mature stage. On the other hand, there are many *Aegicera s corniculatum* and *Kandelia candel* saplings and seedlings in the understory of other 5 associations, and their survival curves fit the Deevey type III. It is indicated that *Kandelia candel* associations or *K andelia candel* + *Aegiceras corniculatum* associations are in the developing succession stage. In the mature mangroves, trees are about 20 years old and reach a canopy height of approximately 4 to 5 m, and toward the estuary, the trees are becoming younger and dwarfer. Mangroves may develop from the Shenzhen Bay firstly, as the *Avicennia marina* association develops, litter falls and debris aggrades around this vegetation, and it helps *Kandelia candel* and *Aegiceras corniculatum* to settle. Then the mangroves expand seaward and toward the Shenzhen estuary.

4.4 Importance of mangroves

Mangroves ecosystem is a buffer system where the mud deposits slowly, and the organic matter is decomposed slowly. Mangroves distributing in the polluted estuary areas have some anti-pollution capability. This system can change the pollution matter into unsolvable matter by soil deposition and absorption as ion-exchange reaction happens.

5 Conclusions

1. This region is an important wetland area supported by 6 associations of mangroves: *Kandelia candel* association, *Avicennia marina* association, *Aegiceras corniculatum* association, *Kandelia candel* + *Ae giceras corniculatum* association, *Aegiceras corniculatum* + *Kandelia candel* association and *Acanthu s ilicifolius* association.

2. 6 Species of mangrove plants, 3 species of semi-mangrove plants and an accompany species appear in this research area.

3. From transect I to transect IV, the importance value of *Avicennia marina, Bruguiera gymnorrhiza* and *Kandelia candel* decreases, and that of *Aegiceras corniculatum* increases. In this area, the *Kandelia candel* population and the *Aegiceras corniculatum* population are developing populations with many seedlings and saplings, but the *Avicennia marina* population is in a mature stage with few seedlings and not so many total individuals.

4. According to this research, we suppose that *Aegiceras corniculatum* should be developed in the estuary and the *Avicennia marina* association should be protected.

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