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Chapter 11

Conservation and Uses of Mangroves in Hong Kong and Mainland China

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Abstract. Mangroves are important inter-tidal wetlands on tropical and subtropical coasts and have been seriously damaged. In Mainland China and Hong Kong SAR, mangrove resources have been rapidly destroyed in recent decades due to massive reclamation, infra-structural developments and pollution. Information related to conservation and uses of mangroves in China is often scattered and incomplete. The present chapter aims to review the distribution, functions and uses of mangrove resources, the conservation strategies, and the associated problems in China.

11.1. Introduction

Mangrove ecosystem is found in inter-tidal areas of sheltered coastlines between 35°N and 35°S. The ecosystem includes unique salt-tolerant trees, shrubs, and other organisms with special adaptation to fluctuating water levels which create a stressful environment. The mangrove ecosystem connects terrestrial, freshwater and marine ecosystems together, and is considered as one of the world's most productive ecosystems with high levels of primary productivity (Kaplowitz, 2001). The living biomass and litter production of mangrove forests are very high (Table 1). The litter has rapid decomposition and nutrient cycling, thus exporting large amounts of plant debris (organic matter and nutrients) to outside water, initiating mangrove-derived detritus food chains and food webs, and supporting fisheries and other aquatic production. In addition, mangroves provide habitats for valuable plant and animal species.

On the other hand, the mangrove ecosystem is among the world's most threatened ecosystems, with more than half of the original area already lost in the most heavily impacted areas (Field et al., 1998). For instance, mangrove cover in the Philippines was reduced from 288,035 ha in 1970 to 123,400 ha in 1993, largely as a result of aquaculture development. Increased market integration,

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Table 1: Annual above-ground biomass, total biomass, and litter production (t ha^{-1}) of mangrove forests in China and East Asia.

Country	Region	Mangrove species	Above-ground biomass	Total biomass	Litter biomass
China	Mai Po, HKSAR	*Kandel candel*	129.6	NA	11.07
	Futian, Shenzhen	*Aegiceras corniculatum* and *K. candel*	87.1	121.4	11.69
		Sonneratia apetala and *S. caseolaris*	33.9	45.6	12.18
	Dongzhai, Hainan	*Bruguiera sexangula*	248.5	420.3	11.79
	Hegang, Hainan	*B. sexangula*	NA	NA	12.55
	Wenchang, Hainan	*B. gymnorrhiza*	64.1	91.5	NA
	Jiulongjiang, Fujian	*K. candel*	93.4	162.6	9.21
	Yingluo, Guangxi	*Rhizophora stylosa*	196.2	291.6	6.32
	Beihai, Guangxi	*Avicennia marina*	26.9	52.7	NA
	Danshui, Taiwan	*K. candel*	NA	143.9	NA
Thailand	South Thailand	*R. apiculata*	159.0	NA	6.70
Malaysia	Matang	*R. apiculata*	185.3	209.5	9.71
Philippines	NA	Mixed mangroves	45.9	NA	NA

NA, not available. Lee (1990), Tam et al. (1995a, 1998), Lin (1999), and Wang et al. (2002).

modernization of traditional economies and urban development in recent decades had led to more intensive mangrove exploitation, and even to their removal (Gilbert & Janssen, 1998). In Hong Kong SAR and southeastern coasts of China, mangroves are destroyed due to urbanization, agriculture and aquaculture. China's mangrove coverage has plummeted, from 50,000 ha in the late 1950s to 15,000 ha in year 2000, and currently occupies less than 0.1% of the world's total. Underestimation of the total value and of the impacts of human activities is another major factor contributing to the widespread loss and degradation of mangrove ecosystems. Therefore, it is important to understand the functions and uses of mangrove resources, and compromise the needs of various stakeholders prior to development of a conservation and management plan. The chapter aims to review the mangrove distribution, its uses, conservation, and associated problems in China.

11.2. Mangrove Distribution and Characteristics in Hong Kong and Mainland China

Mangroves in China are distributed in five provinces, namely Guangdong, Guangxi, Fujian, Zhejiang and Hainan, in addition to Taiwan, Hong Kong and Macau Special Administrative Regions (Table 2). The mangroves in Zhejiang do not occur naturally, and the remaining 8 ha of *Kandelia candel* were transplanted in the 1950s (Li & Lee, 1997). The current mangrove coverage is around 15,000 ha, around 0.2% of South and Southeast Asia mangroves. Over 80% of the existing mangroves are secondary forests with an average height of 1–2 m. A total of 26 true mangrove species and 11 associate mangrove species are found in China, representing about 45% of all mangrove species (83 in total) in the world. In China, Hainan has the highest mangrove species richness and the best developed mangrove forests, while Guangdong has 11 true mangrove species and 9 associate mangroves (Table 3). Mangrove plants such as *Sonneratia paracaseloris*, *S. hainanensis*, *Lumnitzera littorea* and *Nypa fruticans* have become rare and endangered species.

The mangrove ecosystems in China also support a diverse group of macrobenthic animals (Table 4) and provide food for other wildlife such as birds. Many diversified species of precious birds have been identified. Around 201 species of birds belonging to 39 families and 17 orders have been recorded in mangroves in China; 83 species are reproductive resident or summer-migrants, and 118 species are traveling or winter-migratory birds (Lin, 1999). The mangrove nature reserves, in particular Mai Po in HKSAR and Futian in Shenzhen, are important stopovers for winter migratory birds flying from Australia to Siberia. Each year, more than 100,000 migrants flying to the southern areas have been recorded in Futian mangroves (Wang et al., 2002).

Table 2: Mangrove Nature Reserves in China.

Region	Name	Time established	Protected area (ha)	Mangrove area (ha)	True mangrove species no.
Hainan	Donzhaigang[N]	1980	5240	1760	20
	Qinglangang[N]	1981	2948	2722	26
	Xingyin[C]	1983	67	NA	12
	Huachang Bay[C]	1984	133	NA	12
	Caiqiao[C]	1986	350	NA	12
	Xingying[C]	1986	133	NA	16
	Qingmeigang[C]	1989	156	30	20
Guangdong	Futian[N]	1984	304	111	7
	Zhanjiang[P]	1991	2000	933	11
	Zhuhai[S]	Plan	ND	60	5
Guangxi	Beilunhe[P]	1990	2680	1207	11
	Shankou[N]	1990	4400	730	12
Fujian	Jiulongjiang[P]	1988	200	108	5
Taiwan	Danshui[P]	1985	733	80	1
HK SAR	Mai Po	1976	380	120	8
Macau SAR		No protection	<1	0	5

NA, data not available; N, national level; P, provincial level and C, local county level; S, suggested to protect. Li & Lee (1997) and Lin & Fu (1995).

11.3. Uses and Functions of Mangroves

11.3.1. Uses of Mangroves in the World

Table 5 summarizes the possible uses of mangrove resources. It is obvious that mangroves play an important role in maintaining a healthy coastal ecosystem by exporting large quantities of detritus and supplying abundant food and feed to aquatic organisms, maintaining nutrient cycling, biogeochemical functions and energy flow along complex food chains and food webs. It also provides a habitat for a variety of animals especially waterfowl and wintering birds, and acts as a nursery for juvenile species through provision of food and shelter from predation. The prop roots and pneumatophores of mangrove plants, and the shading effect under the leaf canopy allow the small animals escape or hide from their predators.

In addition to ecological functions, mangrove ecosystems are important to the subsistence livelihoods of tropical coastal communities (Kaplowitz, 2001). At present, millions of coastal dwellers throughout the region are dependent on

Table 3: True mangrove species in Guangdong Province, China.

Family	Species	Zhanjiang	Zhuhai	Futian	HKSAR	Macau
Rhizophoraceae	*Bruguiera gymnorrhiza*	+	+	+	+	+
	Ceriops tagal	+	−	−	−	−
	Kandelia candel	+	+	+	+	+
	Rhizophora stylosa	+	−	−	−	−
Acanthaceae	*Acanthus ebractearas*	+	−	−	−	+
	Ac. ilicifolius	+	+	+	+	+
Combretaceae	*Lumnitzera racemosa*	+	−	+	+	+
Euphorbiaceae	*Excoecaria agallocha*	+	+	+	+	−
Myrsinaceae	*Aegiceras corniculatum*	+	+	+	+	+
Sterculiaceae	*Heritiera littoralis*	+	−	+	+	−
Avicenniacea	*Avicennia marina*	+	−	+	+	+
Total		11	5	8	8	7

mangroves for their livelihoods. Mangrove ecosystems can be directly exploited by extracting fish, agricultural products, and wildlife, as well as a variety of other goods including wood for fuel, construction and building materials, drugs, chemicals, feed and food (Kovacs, 1999). Mangrove ecosystems and their ecological functions also provide an array of important indirect services for people such as prevention of storm damage, flood and water control, support of fisheries, pollution mitigation, recreation and transport.

Positive correlations between mangrove areas and near-shore fish and shrimp catches have been demonstrated in many countries including the Philippines, Malaysia, Indonesia, and Australia, with an annual fisheries related income ranging from US$ 66 to almost US$ 3,000 per ha of mangrove (Baran & Hambrey, 1998). In Southeast Asian countries like Thailand and Indonesia, the estimated annual income from fisheries, forestry and agriculture was around US$117–130, $30–67, and $165 per ha of mangroves, respectively (Gilbert & Janssen, 1998).

Table 4: Benthic macrofauna in China mangroves in terms of number of species in each group, density (number of individuals m^{-2}) and biomass (g m^{-2}).

Family	Dongzhai, Hainan	Futian, Shenzhen	Hong Kong SAR	Longhai, Fujian
Annelida: Polychaetes	29	5	2	41
Mollusca: gastropods and bivalves	51	37	52	51
Crustacea: shrimps and crabs	32	27	26	57
Osteichthyes: fishes and mudskippers	4	11	3	11
Other animals	4	4	17	12
Total species no.	138	84	100	172
Density	249	55–1,305	24 (5–44)	311
Biomass	150	29–78	116	48
References	Jiang et al. (1997)	Yu et al. (1997)	Cai et al. (1997); Tam & Wong (2000a)	Jiang & Li (1995)

In the Philippines, the estimated net annual economic values of wood and fish products from managed mangroves were US$90 and $538 per ha mangroves, respectively (De Leon & White, 1997). The income generated from mangrove wood production and agriculture is poorly understood as it varies from species to species, and the best species for local uses is often not clear due to lack of systematic studies (Kovacs, 1999).

The estimated values of the services derived from mangroves (e.g. shoreline protection against erosion, food and wood production, and habitat for wildlife) at US$10,000 per ha per year were reported by Costanza et al. (1997). Mangrove wetlands have long been used as convenient sites of waste disposal and have often received untreated wastewater from human activities (Clough et al., 1983). The feasibility of using mangroves to remove pollutants from municipal sewage, livestock wastewater and shrimp effluent has been examined since 1990s (Robertson & Phillips, 1995; Wong et al., 1997; Rivera-Monroy et al., 1999; Tam & Wong, 1999). Integrated pond–mangrove farming systems with wetland to shrimp pond ratios varying from 1:2 to 1:22 have been proposed; depending on the capacity of mangrove sediments to remove nitrogen relative to the anticipated loading rate (Robertson & Phillips, 1995) the ratio could be lowered to a range of 1:0.04–1:0.12 if denitrification process takes place in the mangrove wetland

Table 5: Uses and functions of mangroves.

Uses	**Examples**
Ecological	Maintain functions of ecosystem: nutrient cycling and biogeochemical function Support biodiversity Provide wildlife habitat and nursery for juveniles and post-larvae
Consumptive use for harvestable products	Mangrove woods: timber, charcoal and fuel wood, construction and building Fisheries and aquaculture: fishes, shrimps, *gei wai* prawns, snails, and crab cultivation and collection Farming: paddy and rice fields Salt extraction Tannin extraction Medicine: Chinese herbs Bioactive compounds and chemicals extraction
Non-consumptive uses	Recreation: ecotourism, picnics and aesthetic values Storm protection: prevent erosion, flood and water control Pollution mitigation: wastewater treatment, waste adsorption and absorption Education, training, and scientific research

system (Rivera-Monroy et al., 1999). The mangrove sediments are effective in retaining nutrients and heavy metals from wastewater, and the estimated amounts of nitrogen and phosphorus removed from a mangrove system ranged from 0.18–87.6 mg N m^{-2} day^{-1} and 2.7–9.9 mg P m^{-2} day^{-1}, respectively (Clough et al., 1983; Chen et al., 1995; Robertson & Phillips, 1995; Tam & Wong, 1996).

11.3.2. Functions of Mangroves in China

In history, mangroves were of great value in China and almost all uses listed in Table 5 have been practiced. Mangrove woods have been used to make furniture and small boats (Lin, 1999). However, due to the relatively small sizes of mangroves in China, and the lack of planned reforestation, mangroves are not suitable for economic uses as wood and fuel resources. Seeds, fruits and hypocotyls have been consumed by humans especially in early 1960s. The hypocotyls of *Bruguiera* spp., *Rhizophora* spp. and *K. candel*, containing high

concentrations of starch, have been sliced and ground into powder for making cakes or used as sweetened stuffing for pastry, while salted seeds and fruits of *A. marina* and *S. caseolaris* have been eaten for breakfast and banquets (Lu & Lin, 1987) after being soaked in water for several hours to rinse out tannin substances. The mangrove plants in China have been widely used as traditional herbal medicines (Table 6) but very poorly documented historically, and much information is based on conventional wisdom and anecdote. There is no research or scientific proof for their effectiveness. The food/feed and medicinal potential of mangrove plants deserves further research and development work.

Aquaculture has been practiced in China for many years. The mangrove benthic species with high commercial values including *Sipunculus nudus* (worm), *Phascolosoma esculenta* (known as To Sun Dong, a traditional local snack in Xiamen), *Pinctada martensi* (pearl-mother shell for pearls), *Meretrix meretrix* (shell), *Saccostrea cucullata* (oyster), *Scylla serrata* (crab), *Metapenaeus monoceros* (shrimp), *Bostrichthys chinensis* (fish), and various species of mullets,

Table 6: Medicinal uses of true mangrove plants in Guangdong, China.

Species	Plant part	Medicinal uses
Kandelia candel	Root	Chronic arthritis
Bruguiera gymnorrhiza	Fruit and hypocotyl	Diarrhea, malaria and diabetes
	Leaf	Malaria
Rhizophora stylosa	Bark	Purify bloody urine
Ceriops tagal	Bark, seed and leaf	Hemostasis, astringent and scabies
Avicennia marina	Leaf	Skin abscess, diuretic
	Trunk and bark	Contraceptives, diuretic
	Fruit	Diabetes
Acanthus ebracteras	Fruit	Furuncle
Acanthus ilicifolius	All parts	Analgesic, swelling relief, leukemia, cancer, skin itches and abscess
	Leaf	Rheumatic pain
	Fruit and root	Snake wound, hepatitis B, impotence (male sterility)
Lumnitzera racemosa	Juice of trunk	Aphtha
	Bark	Diabetes, kidney stone
Excoecaria agallocha	Bark	Diarrhea
	Leaf	Epilepsy
	Wood burning	Leprosy
Heritiera littoralis	Bark	Haematuria, diarrhea

Lin (1999) and Lin & Fu (1995).

mudskippers and sand borers have been cultivated and give economic benefits to the local community (Lin, 1999). Lin & Fu (1995) estimated that the yearly output of *Scylla serrata* in Hainan Donzhaigang mangroves was more than 30,000 kg.

In recent years, more efforts have been placed to explore the aesthetic values of mangroves and to promote ecotourism. People can do canoeing, fishing, picnicking, observing the behavior of birds and animals, and understanding the adaptation of plants in mangrove forests. Tourists can appreciate the beauty of nature and simultaneously understand the ecosystems and biodiversity, which can enhance their awareness on mangrove conservation. Mai Po and Futian Mangrove Nature Reserves have been successful in developing education and research programs, school visits and guided tours. In 1997, over 40,000 students and public visited Mai Po Nature Reserve without compromising its conservation value. The Dongzhaigang Mangrove Nature Reserve in Hainan is the largest tourist zone for mangrove sightseeing in China, and has attracted more than 200,000 visitors since 1980 (Lin & Fu, 1995). Other mangroves such as Shankou National Nature Reserve in Hepu, Guangxi and Qinglangang Mangrove Nature Reserve in Hainan are also planned for mangrove ecotourism. Although tourism gives economic benefits to the local community and brings additional funds for mangrove conservation, it also generates damages and disturbances, in particular, the need for more food and accommodation facilities, and pollution generating from human activities. How to compromise these conflicts and achieve real ecotourism still needs further research. The carrying capacity of a mangrove environment must be properly estimated and the potential damage must be understood before converting China mangroves into tourist spots.

11.4. Conservation of Mangroves

11.4.1. General Principles

The regional and local losses of mangroves have attracted more and more attention, and emerging awareness of the societal costs has encouraged a recent trend towards preservation and restoration of mangroves. The importance of mangroves started to be realized in 1978 when UNESCO's Scientific Committee on Oceanic Research established a working group on mangrove ecology. The mangrove ecosystem was identified as an endangered ecosystem in 1980s, and a working group on mangrove ecosystems was created by IUCN (International Union for the Conservation of Nature) (Ellison & Farnsworth, 1996). Many conferences have been convened by UNESCO, UNDP and UNEP, and have formulated "Charter for Mangroves" with ISME (the International Society for Mangrove Ecosystem) for further understanding on each country's mangrove features and related protection measures.

For better conservation and management of mangrove ecosystems in a sustainable manner, it is essential to have a clear understanding of the features and ecological functions of mangroves in local contexts to properly estimate the uses and values of mangroves, and to address the needs and interests of all stakeholders in the system. In a mangrove ecosystem, due to its complexity and multiple ecological and socio-economic functions (Tables 5 and 6), various stakeholders are involved. These include (a) primary stakeholders: local communities whose livelihoods are directly dependent on mangrove resources such as fishermen, paddy farmers, wood makers, and others; (b) key stakeholders: government officials, developers, and resource economists whose actions directly affect decision-making; (c) secondary stakeholders: tourists and traders who have an interest on the mangroves but without any direct involvement; and (d) ecologists and conservationists who have strong view to preserve the nature of the mangroves. Proper trade-offs and negotiation, to balance the gains and losses amongst all stakeholders, are essential processes to solve conflicts before decision-making. The arrays of benefits flowing from mangrove ecosystems perceived at the local level are important considerations. A success and sustainable conservation plan will rely on how these views on mangrove functions and values are cared for and understood.

In view of the fact that mangroves often cover a large area and are scattered in different sites within a region, and that resources and manpower are always limited, it is important to prioritize sites worthy of conservation. These sites can only be identified and selected after taking into account of all available and relevant scientific, social, economic and cultural values. However, detailed information relating to the distribution of the biota to be protected, the socio-economic data, the degree of pollution and human disturbance is largely unavailable, and obtaining such data is often expensive and time consuming.

11.4.2. Conservation of Mangroves in HKSAR

In Hong Kong SAR, mangroves were used in the past for production of salts, shrimps, and other fisheries, but they are not used for any commercial production at present. They are mainly conserved to maintain the natural functions and processes of the ecosystem, biodiversity, and habitats for birds and wildlife. They are scattered in more than 40 different enclosed bays, in addition to the largest area in Mai Po Nature Reserve. In order to assess and prioritize the conservation values of these scattered mangroves, a comprehensive study was conducted in 1994–1997 to investigate the distribution, ecological and socio-economic characteristics of 43 mangrove swamps still remaining in Hong Kong (Tam et al., 1997; Tam & Wong, 2000a, 2002). Nine criteria covering ecological, economic and social aspects were use to develop a conservation score for each mangrove swamp, and

the swamps were classified into five categories according to their scores. The extremely important swamps have been conserved immediately (Tam & Wong, 2002). Among the 10 conservation strategies recommended, enforcement of existing ordinances and legislation, environmental education and community actions to promote public awareness, and replanting are found to be the most effective and suitable measures in HKSAR, and have been adopted by local government (Tam & Wong, 2000a, 2002).

11.4.3. Conservation of Mangroves in Mainland China

As early as in the 19th century, the Chinese had recognized the importance of mangroves, and penalized people who caused damage, while rewarding those who planted mangroves (Field, 1996). In the 1950s, the total mangrove area in China was around 50,000 ha, but more than 30,000 ha of mangrove, with an annual loss of 600 ha, have disappeared in the last 50 years (Table 7). Since 1980s, China has started to protect mangroves from disturbance by establishing mangrove nature reserves. Since then, 14 mangrove nature reserves including Mai Po in Hong Kong SAR and Danshui River in Taiwan have been established to protect around 8,000 ha of mangrove, around 44% of existing mangroves in China (Table 2).

Table 7: Damages of mangroves in China in 1950–2000.

Year	Region	Area of damages (ha)	Reasons
1960s–1970s	Fujian, Guangdong and Guangxi	Massive	Conversion to farmland for crop production
	Hainan Island	4,667	Conversion to rice fields
1980s	Fujian	470	Enclosed as ponds for cultivation of prawns, crabs and eels
	Guangdong	13,972	Conversion to shrimp and prawn farms
Mid 1980s onwards	Guangdong	Massive	Urban and infra-structural development
	Futian	48	Infra-structural development
	Zhuhai	1,350	Urban and infra-structural development, and pollution

Modified from Lin & Fan (1992) and Wang et al. (2002), and personal communication.

In each nature reserve, three zones, namely core, buffer and experimental (research) are established. For instance, the Futian National Nature Reserve established in 1984 had a total area of 415 ha, and the core, buffer and experimental zones occupied 203, 65 and 37 ha, respectively. In recent years, due to infra-structural developments in Shenzhen, the area of the Futian nature reserve has been reduced to 367 ha with 44, 14 and 39% as core, buffer and experimental zones, respectively (Wang et al., 2002). Within the core zone of each nature reserve, utilization and interference from external factors are restricted, and the mangroves are undisturbed and left in their natural state in order to maintain the biodiversity, ecological processes and functions. In the buffer zone, ecological tourism and sustainable utilization of mangroves for aquaculture (e.g. *gei wai* ponds in Futian, Shenzhen; oyster culture in Shankou, Guangxi; Pearl Culture in Dongzhaigang, Hainan) and other purposes are carried out through appropriate management plans. Research, education, training and community action programs are taken place in the research and experimental zone. The goals and objectives of each nature reserve vary slightly (Table 8).

11.4.4. Mangrove Planting and Restoration

In view of the significant loss of mangrove habitats in past decades, one of the important conservation measures is to restore mangrove habitats by planting and replanting. Technologies required for mangrove replanting and restoration are neither new nor complex. Several hundred mangrove restoration projects have been undertaken around the world, initially confined to First World and Caribbean nations, and have recently been spread to South and East Asia (Field, 1996). Mangroves have been planted as part of a forestry management regime and as a coastal protection measure in countries such as Thailand, Malaysia, Indonesia, the Philippines and Bangladesh. However, most of these are economic plantation projects intended to yield firewood, construction timber, or other forestry products for livelihood improvement of the local community. The results often resemble monotypic, even-age stands cultivated by commercial forestry operators, with little consideration on ecological restoration.

In China, in contrast to other countries in East Asia, economic planting for direct extraction of mangrove products is not the major objective, and large-scale planting projects for woods are uncommon. Instead, more consideration has been placed on enhancing the ecological values of the mangroves, i.e. preservation. In most regions in China including Hong Kong SAR, the inter-tidal zones, compared to those in tropical regions, are relatively narrow which limits the mangrove coverage. Recent reclamation and urban development projects further destroy mangroves at the seafront. The mangrove coverage at present often exists as a thin

Table 8: Major objectives of mangrove conservation in some nature reserves in China.

Region	**Name**	**Protection level**	**Conservation objectives**
HKSAR	Mai Po	Part of RAMSAR	Ecological habitat for biodiversity; stopover for migratory birds; water fowling and wildlife; education, training and scientific research
Shenzhen	Futian	National Nature Reserve	Ecological habitat; important stopover for migratory birds; ecotourism; education, scientific and applied research
Guangxi	Shankou	National Nature Reserve	Ecological habitat and biodiversity; pearl oyster culture for "Southern Pearls"; develop offshore fishery; protecting sea shore and terrestrial resources; scientific research
Hainan	Dongzhaigang	National Nature Reserve and RAMSAR	Protect wetland habitat and biodiversity; develop sustainable ecotourism and related business; education and scientific research
Fujian	Jiulongjiang (Longhai)	Provincial Nature Reserve	Ecological habitat; protect sea shore from erosion; historic attraction; scientific research

belt (<40 m) with relatively low ecological and economic values. Therefore, the main aim of planting is to increase the mangrove extent, and create a "green wall" along coastlines. A successful ecological planting project should aim for multiple species enrichment planting in order to increase both the extent and biodiversity of the planted forests. However, planting in Hong Kong SAR and Mainland China is often limited to viviparous species, with obvious droppers such as *Kandelia candel* or *Bruguiera gymnorrhiza* (Tables 9 and 10). In recent years, planting in Mainland China has concentrated on rapid growing of the exotic pioneer species, *Sonneratia*, as planting native species such as *Aegiceras corniculatum* and

Table 9: Mangrove planting projects in Hong Kong SAR.

Place	Year	Area/no. of plants	Species planted	Purposes	Organization
Sheung Pak Nai, Deep Bay	1980s–present	4 km along coastlines	*K. candel*, *B. gymnorrhiza*, and *A. corniculatum*	Protect fish ponds from erosion	Local farmers
Tin Shui Wai Creek, Northwest New Territories	1994	10m wide, 20–100m long along the creek	*K. candel*	Compensate loss due to Tin Shui Wai New Town reclamation	Territory Development Department, HK Government
Yuen Long and Kam Tin, Northwest New Territories	1995	34 ha	*K. candel*, *B. gymnorrhiza*, *A. corniculatum*, and *Ac. ilicifolius*	Mitigation for loss along drainage channels	Territory Development Department, HK Government
Wong Chuk Wan, Sai Kung	1995–present	80,000 droppers	*K. candel* and *B. gymnorrhiza*	Green action	Friends of Earth, HK (FOE)
Kei Ling Ha Lo Wai, Sai Kung	1999–present	No record	*K. candel*, *B. gymnorrhiza*, and *A. corniculatum*	Green and community action	FOE, Ocean Park Conservation Foundation
Kau Sai Chau	1995–1997	1.64 ha	*K. candel*, *B. gymnorrhiza*, and *A. corniculatum*	Compensate loss due to public golf construction	Jockey Club, HK
Tai O	Plan to start in 2005	12 ha	Multiple and mixed species	Mitigation for loss due to Chek Lap Kok Airport construction	HKSAR Governments

Table 10: Mangrove planting and restoration projects in Mainland China.

Place	Year	Area/no. of plants	Species planted	Purposes	Organization
Qinzhou, Guangxi	1956–1965	7 ha	*Av. marina*	Animal feed	Local farmers
Haikang, Guangdong	1956–1965	100 ha	*R. stylosa*	Protect land farm, fish ponds and houses	Local people
Longhai, Fujian	1958	No record	*K. candel*	Protect erosion	Local people
Dongzhaigang, Hainan	1980–1990	173 ha	*K. candel*, *B. gymnorrhiza*, *B. sexangula*, *X. granatum*, *R. apiculata,* and *R. stylosa*	Conservation	Nature Reserve
Futian, Shenzhen	1986–1998	>50 ha	*K. candel*, *A. corniculatum*, *B. sexangula*, *S. caseolaris*, *S. apetala*	Expand the mangrove belt, and conservation	Nature Reserve

(*continued*)

Table 10: Continued.

Place	Year	Area/no. of plants	Species planted	Purposes	Organization
Zhanjiang, Leizhou Peninsula, Guangdong	1985–1994	>1,200 ha	*A. marina*, *R. stylosa*, *K. candel*, and *B. gymnorrhiza*	Conservation	Nature Reserve
	2001–present	50 ha	*S. apetala*	Create a green belt	Local government
Qinzhou, Guangxi	1982–1984	1,400 ha	*A. corniculatum*	Conservation	Local government
Xiamen, Fujian	1996–2001	107 ha along 2.3 km coastlines	*K. candel*	Create a green belt	Local government
Zhuhai, Guangdong	1999–present	140 ha	*S. apetala*, *R. stylosa*, *B. gymnorrhiza*, and *H. littoralis*	Create a green belt	Local government
Dongxin, Guangxi	2000	600 ha	Not record	Conservation	Local government
Dazhou Island, Maoming, Guangdong	2001–2002	660 ha	Not record	Develop a sea forest park	Local government
Punyu, Guangdong	2002	15 m wide × 15 m long	*S. apetala*	Conservation	Local government

Avicennia marina has failed most times. More research is needed to develop planting methods for non-viviparious and rare species, and to understand the long-term impacts of exotic mangrove species. It is also important to create nurseries for research, and the continuing supply of mangrove propagules for planting and reforestation.

11.5. Problems and Possible Solutions in Mangrove Conservation

11.5.1. Habitat Loss Due to Land-Use Change

Land-use change leading to habitat loss is one of the major threats to mangroves. As shown in Table 7, mangroves in China were mainly destroyed due to conversion of mangroves to salt pans, *gei wai* ponds, shrimp and crab farms, fisheries and paddy fields during the period 1950–1980s. In recent decades, urbanization, reclamation and infra-structural developments have destroyed most mangroves along coastlines. In Shenzhen, 36 ha of mangroves have been destroyed since 1991 (Wang et al., 2002). In Hong Kong SAR, 7 ha of mangroves were lost due to construction of Chek Lap Kok Airport, and 85 and 42% of the original mangrove cover in Deep Bay and Tolo Harbor were lost since the 1970s, respectively (Tam et al., 1997). It is obvious that mangrove preservation requires land use planning decisions. In Hong Kong SAR, important mangrove areas have been included as Country or Marine Parks, Sites of Special Scientific Interests (SSSIs) and Coastal Protection Areas on relevant Outline Zoning Plans (OZPs) or Development Permission Area Plans (DPA). Any development taking place in areas having mangroves of high conservation values will require planning permission from the Town Planning Board, and prevention, minimization, mitigation and compensation measures for mangroves, based on ecological impact assessment, must be included. In the Mai Po and Inner Deep Bay RAMSR site, planning control in the buffer zone is enforced to discourage developments, and the concept of no net loss of wetlands has been adopted by the Town Planning Board, Hong Kong SAR Government since 1999.

11.5.2. Water Pollution and Human Disturbance

Water pollution is another important threat to mangroves in both HKSAR and Mainland China as mangroves are located in sheltered and relatively slow-flushing bays. Deep Bay with increased pollution from Shenzhen River and other local feeders is famous for its pollution, mainly due to discharges of untreated or

partially treated wastewater from cities and villages in HKSAR and Shenzhen Special Economic Zone (Richardson et al., 2000). Table 11 summarizes the degree of pollution in HKSAR, Shenzhen and other mangroves. Pollution loads arise from urban, industrial and agricultural sources within the mangrove areas, and the catchments must be reduced and restricted. The governments should make efforts to install or upgrade sewage treatment plants to keep pace with the rapid economic development in the areas, tighten the discharge standards, and take enforcement actions on industrial and agricultural illegal discharges. Other human disturbances, such as illegal cutting, refuse dumping, eutrophication and algal blooms, and accidental discharge of toxic pollutants, which have also killed mangrove plants, must be controlled.

11.5.3. Lack of Ecological and Baseline Data

One problem in conserving mangroves is lack of understanding regarding its ecological features. A long-term monitoring program aiming to quantify baseline conditions of the area, and to detect any changes in the ecological characteristics of the site, is essential. In Mai Po RAMSAR, the HKSAR Government is currently implementing its Conservation Strategy and Management Plan with a long-term monitoring program. Similarly in Mainland China, permanent plot studies and long-term monitoring have been carried out in Futian, Hainan Dongzhaigang, and Guangxi Shankou mangrove reserves (Lin, 1999).

11.5.4. Insect Infestation and Exotic Species Invasion

Insect infestation is another recent problem in HKSAR and Guangdong Province. Since 1990s, *Avicennia marina*, the pioneer and dominant species, has suffered from serious attacks by caterpillars of two moth species, *Pseudocatharylla duplicella* and *Oligochroa cantonella*, and *Palliphera nobilis* from April to June every year. Such attack causes massive defoliation (more than 80% of leaves were eaten) leading to a failure in the production of fruits and seeds (Wang et al., 2002). In Futian, three pest insects were recorded in 1994 with a large piece of *Av. marina* being killed, and the number increased to nine in 1999. The major insect attacking *K. candel* and *A. corniculatum* is *Amatissa* sp. although its damage is still tolerable. The deterioration of the surrounding habitats and the loss of terrestrial plants and birds are possible reasons for the pest insect outbreaks. Improving the habitat quality at the back of the mangroves in order to support a diverse group of organisms is the best biological control. In Futian Nature Reserve, plans have been suggested to restore landward vegetation and the associated animal populations.

Table 11: Concentrations of heavy metals ($\mu g\ g^{-1}$), polychlorinated biphenyls (PCBs $\mu g\ kg^{-1}$) and PAHs (polycyclic aromatic hydrocarbons $\mu g\ kg^{-1}$) in mangrove sediments.

Pollutant	HKSAR mean and range[a]	Polluted sites in Futian, Shenzhen mean and range[b]	Futian Shenzhen, mean and range[c]	Futian, Shenzhen mean[d]	Yingluo, Gangxi mean[d]	Jiulongjiang, Fujian mean[d]
Cd	0.67–2.26	1.6 (0–2.0)	2.96 (0.27–7.94)	0.14	0.077	0.094
Cr	3.80–129	NA	34.2 (6.8–56.7)	7.97	9.27	4.73
Cu	6.85–75.5	58.1 (7.1–127)	41.1 (15.8–308)	38.3	18.9	29.7
Mn	34–223	NA	438 (124–789)	537	583	583
Ni	4.68–30.2	NA	NA	25.0	14.6	16.9
Pb	28.9–85.4	59.8 (18.7–81.3)	35.4 (0.1–423)	28.7	10	18.3
Zn	50–263	146 (66–202)	146	114	47	111
PCBs (Tam & Yao, 2002)	3.86 (0.1–25.1)	NA	NA	NA	NA	NA
PAHs (Tam et al., 2001)	1,992 (356–11,098)	7,274 (1,218–14,466)	NA	2,196 (408–10,811)	NA	NA

NA, not available.
[a] Tam & Wong (2000b) for metals.
[b] Wang et al. (2002).
[c] Tam et al. (1995b).
[d] Lin (1999).

In addition to insects, invasion by exotic species, in particular *Mikania micrantha* — a noxious species originating from South America, has become a problem in the HKSAR and Futian mangroves. As a climber with rapid growth and reproductive rates, this weed grows over and kills the host. How to control this weed is still uncertain as the plant recovers rapidly from the remnant propagules (within 6 months) after manual cutting (Wang et al., 2002). Another exotic species causing threats to mangroves in Zhuhai, Guangdong and Mai Po, HKSAR is *Spartina anglica* (a grass) which occupies the mudflats and restricts tidal flow, thus limiting the dispersion and development of mangrove fruits, seeds and propagules.

11.5.5. Insufficient Resources and Lack of Integration Between Various Departments

Resources and manpower allocated to mangrove are often limited. Too many government departments are involved in mangrove conservation, including the Ministry of Forestry, Ministry of Agriculture, National Marine Bureau and National Environmental Protection Bureau, but without clear responsibility and coordination. Insufficient resources and lack of communication often lead to poor management, even in the core and buffer zones, and illegal intrusion and development within these zones are common in China.

To strengthen the protection and management of mangroves in China, a leading group on Mangrove Conservation and Management was formed in April 1995, and adopted the principle of integrated and coordinate mangrove conservation (Tam & Wong, 2002). In the 1990s, China stepped up its efforts to protect mangroves, with aims to conserve and restore this endangered coastal ecological system. A draft plan in 1998 was made. Local governments, in particular Fujian province has also passed and enforced regulations to protect the mangroves. In 1998, Wetland International-Asia Pacific China Program (WIAPCP), a non-profit international environmental protection organization, implemented a US$ 25,000 conservation project at Hainan Donzhaigang Mangrove Reserve, and proposed a US$ 5 million project for comprehensive protection of the Zhanjiang Mangrove Reserve. Under a project financed by the United Nations Environment Program, China will receive US$ 10 million over 10 years to protect its mangroves and their wetland habitats (website: http://www.oneworld.org/ips1/apr00/08_36_010.html). With a better understanding of mangrove characteristics, functions and problems, together with the development of proper conservation plans, and the allocation of sufficient funds, then mangroves in China would be well protected from man-made threats.

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