USEFUL PRODUCTS FROM MANGROVE AND OTHER COASTAL PLANTS

Shigeyuki Baba, Hung Tuck Chan
& Sanit Aksornkoae



ISME Mangrove Educational Book Series No. 3

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International Society for Mangrove Ecosystems (ISME),
c/o Faculty of Agriculture, University of the Ryukyus,
1 Senbaru, Nishihara, Okinawa, 903-0129 Japan

International Society for Mangrove Ecosystems

International Tropical Timber Organization

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Cover photographs:

General view of the Urauchi mangroves in Iriomote, Japan

Aboriginal sculptures from *Xylocarpus* wood in Selangor, Malaysia

Women collecting *Avicennia* foliage as fodder in Gujarat, India

Fabric dyed with *Rhizophora* bark tannin in Iriomote, Japan

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ISME and ITTO

ISME

The International Society for Mangrove Ecosystems (ISME) is an international non-profit and non-governmental scientific society established in August 1990. With its headquarters in Okinawa, Japan, ISME was certified as a Foundation in 1992 by the Japanese Law of Foundation. In 2003, under a new Japanese law of promoting specified non-profit activities, ISME was registered as a Non-Profit Organization (NPO). Revised at the Eighth General Assembly in 2012, the Statutes of ISME stipulate that 'the Society shall collect, evaluate and disseminate information on mangrove ecosystems', and 'shall promote international cooperation'. ISME has been carrying out its activities at the global level through: a) application of knowledge to particular situations, b) training and education, and c) exchange of necessary information. Activities of the society have been supported with collaboration and links by a number of other organizations, universities, research institutes and local communities. Currently, ISME's membership includes 40 institutions and over 1,150 individuals from 92 countries.

ITTO

The International Tropical Timber Organization (ITTO) is an intergovernmental organization promoting the conservation and sustainable management, and the use and trade of tropical forest resources. Its 65 members represent most of the world's tropical forests and 90% of the global tropical timber trade. ITTO develops internationally agreed policy documents to promote sustainable forest management and forest conservation, and assists tropical member countries to adapt such policies to local circumstances and to implement them in the field through projects. In addition, ITTO collects, analyses and disseminates data on the production and trade of tropical timber, and funds projects and other actions for developing industries at both community and industrial scales. All projects are funded by voluntary contributions, mostly from consumer member countries. Since it became operational in 1987, ITTO has funded more than 800 projects, pre-projects and activities valued at more than USD 350 million. The major donors are the governments of Japan, Switzerland, EU and USA.

About the Authors

Shigeyuki BABA

Prof. Baba obtained his Ph.D. from the University of Kyushu in Japan. A Professor of University of the Ryukyus in Okinawa, he served as the Deputy Executive Secretary and Executive Secretary of the International Society for Mangrove Ecosystems (ISME) since inauguration of the society in 1990. Being the Executive Director of ISME (from 2011), he has coordinated all the projects implemented by ISME. He continues his untiring efforts in seeking funds to support on-going and future projects of the society.

CHAN Hung Tuck

Dr. Chan obtained his Ph.D. from the University of Aberdeen in Scotland. A former Division Director of the Forest Research Institute Malaysia, he served as the Vice-President of ISME (from 2005) and as the Treasurer of ISME (from 2011). He was appointed the Project Coordinator (PC) of the ITTO/ISME Pre-Project 134/07 Rev. 1 (F), and the PC and Editor of ITTO/ISME Small Project 564/09 Rev. 1 (F). Currently, he is the Editor of *ISME/GLOMIS Electronic Journal* and the Producer of *ISME Newsletter*.

Sanit AKSORNKOAE

Prof. Aksornkoae obtained his Ph.D. from the Michigan State University in the USA. A retired Professor Emeritus and Vice-President of Kasetsart University, and a former President of Thailand Environment Institute, Bangkok, Thailand, he is currently the President of ISME (from 2011). He has coordinated many projects and published numerous papers relating to mangroves in Thailand.

Preface

This book *Useful Products from Mangrove and other Coastal Plants* is the third in a trilogy to be published simultaneously. The others are *Continuing the Journey Amongst Mangroves* by Barry Clough, and *Structure, Function and Management of Mangrove Ecosystems* by Jin Eong Ong and Wooi Khoon Gong.

In this book, all traditional and recent uses of wood and non-wood products in different regions of the world are substantiated by case studies. A total of 72 case studies have been described of which 22 are on wood products and 50 are on non-wood products. Chapters 2 and 3 are case studies on traditional and recent wood products, and Chapters 4 and 5 are case studies on traditional and recent non-wood products, respectively.

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Under the project, three books representing the beginning of the *ISME Mangrove Educational Book Series* are produced. They are written, published and launched in commemoration of Prof. Shigeyuki Baba, the Executive Director of ISME, who will be retiring from University of the Ryukyus in March 2013.


Photo: K. Tsuruda


Photo: H.T. Chan

Chapter 1

INTRODUCTION

Mangrove Plants

Mangroves are plant communities of the intertidal coastal zone in the tropics and subtropics. These trees, shrubs and herbs have developed morphological, physiological and/or reproductive strategies adapted to the harsh saline, waterlogged and anaerobic environmental conditions (e.g. Tomlinson, 1986; Duke, 2006; Hogarth, 2007; Spalding et al., 2010; ITTO, 2012). The strategies include coping with salinity through ultra-filtration and salt glands; aerating roots with lenticels to facilitate gaseous exchange; vivipary and crytovivipary to enable rapid establishment and early growth of seedlings; and buoyant propagules to facilitate water dispersal. These adaptations of mangrove plants have been comprehensively described in companion volumes to this book by Clough (2013) and Ong & Gong (2013).

Mangrove species can be categorised into true mangroves and mangrove associates (Selvam, 2007; Wang et al., 2011). True mangroves are exclusive species, which are adapted to the mangrove habitat, and do not extend into other terrestrial plant communities. Plants that occur in the coastal environment and also within mangroves are considered as mangrove associates or non-exclusive species. A total of 52 species have been identified by Giesen et al. (2007) as true mangroves in Southeast Asia (Table 1.1). Mangroves that are dominant and typify the flora in most locations are considered as core species (Spalding et al., 2010; ITTO, 2012). Globally, a total of 38 core species have been identified in the Indo-West Pacific and Atlantic East Pacific regions (Table 1.2).

Table 1.1 True mangrove species in Southeast Asia (Giesen et al., 2007)

Acanthus ebracteatus	*Brownlowia argentata*	*Lumnitzera littorea*
Acanthus ilicifolius	*Brownlowia tersa*	*Lumnitzera racemosa*
Acanthus volubilis	*Bruguiera cylindrica*	*Nypa fruticans*
Acrostichum aureum	*Bruguiera exaristata*	*Osbornia octodonta*
Acrostichum speciosum	*Bruguiera gymnorhiza*	*Oberonia rhizophoreti*
Aegialitis annulata	*Bruguiera hainesii*	*Pemphis acidula*
Aegialitis rotundifolia	*Bruguiera parviflora*	*Rhizophora apiculata*
Aegiceras corniculatum	*Bruguiera sexangula*	*Rhizophora mucronata*
Aegiceras floridum	*Camptostemon philippinense*	*Rhizophora stylosa*
Amyema anisomeres	*Camptostemon schultzii*	*Scyphiphora hydrophyllacea*
Amyema gravis	*Ceriops decandra*	*Sonneratia alba*
Amyema mackayense	*Ceriops tagal*	*Sonneratia apetala*
Avicennia alba	*Excoecaria agallocha*	*Sonneratia caseolaris*
Avicennia eucalyptifolia	*Heritiera fomes*	*Sonneratia griffithii*
Avicennia lanata	*Heritiera globosa*	*Sonneratia ovata*
Avicennia marina	*Heritiera littoralis*	*Xylocarpus granatum*
Avicennia officinalis	*Kandelia candel*	*Xylocarpus moluccensis*
		Xylocarpus rumphii

Table 1.2 Core mangrove species of the Indo-West Pacific and Atlantic East Pacific regions of the world (Spalding et al., 2010; ITTO, 2012)

Indo-West Pacific			
Avicenniaceae *Avicennia alba* *Avicennia integra* *Avicennia marina* *Avicennia officinalis* *Avicennia rumphiana* **Combretaceae** *Lumnitzera littorea* *Lumnitzera racemosa*	**Meliaceae** *Xylocarpus granatum* *Xylocarpus moluccensis* **Sonneratiaceae** *Sonneratia alba* *Sonneratia apetala* *Sonneratia caseolaris* *Sonneratia lanceolata* *Sonneratia ovata*	**Rhizophoraceae** *Bruguiera cylindrica* *Bruguiera exaristata* *Bruguiera gymnorhiza* *Bruguiera hainesii* *Bruguiera parviflora* *Bruguiera sexangula*	*Ceriops australis* *Ceriops decandra* *Ceriops tagal* *Kandelia candel* *Kandelia obovata* *Rhizophora apiculata* *Rhizophora mucronata* *Rhizophora samoensis* *Rhizophora stylosa*
Atlantic East Pacific			
Avicenniaceae *Avicennia bicolor* *Avicennia germinans* *Avicennia schaueriana*	**Pellicieraceae** *Pelliciera rhizophorae*	**Rhizophoraceae** *Rhizophora mangle* *Rhizophora racemosa*	**Combretaceae** *Conocarpus erectus* *Laguncularia racemosa*

Other Coastal Plants

Other coastal plants are those of beaches and dunes, also referred to as beach or strand vegetation, and those of coral islands (Chan & Baba, 2009). Vegetation of beaches and dunes consists of three zones, namely, the pioneer zone with primary stabilising plants of mainly herbaceous species; the shrub zone with secondary stabilising plants consisting of shrubs, herbs and grasses; and the forest zone consisting of shrubs and trees (Craft et al., 2008). Common plant species found in the various zones of coastal beaches and dunes are shown in Table 1.3.

Table 1.3 Common plant species found in the various zones of coastal beaches and dunes (Chan & Baba, 2009)

Zone	Common plant species
Pioneer	*Ischaemum muticum*, *Canavalia rosea*, *Wedelia biflora*, *Ipomoea pes-caprae* and *Sesuvium portulacastrum*
Shrub	*Spinifex littoreus*, *Vitex trifolia*, *Wedelia biflora*, *Pandanus odoratissimus*, *Pandanus tectorius*, *Scaevola taccada*, *Pemphis acidula*, *Hibiscus tiliaceus* and *Thespesia populnea*
Forest	*Calophyllum inophyllum*, *Terminalia cattapa*, *Barringtonia asiatica*, *Melaleuca cajuputi* and *Casuarina equisetifolia*

In Southeast Asia and the Pacific Islands, two formations of strand vegetation are commonly associated with beaches and dunes (Wibisono & Suryadiputra, 2006; UNEP, 2007; Giesen et al., 2007; Hanley et al., 2008). They are:

Pes-caprae formation: This formation is dominated by the creeper *Ipomoea pes-caprae*, which is a common cover crop of dune strands. If the substrate is stable, the plant will grow rapidly and dominate the back part of the beach. Establishment of this creeper is usually followed by the growth of grasses such as *Spinifex littoreus*, *Cyperus maritime* and *Ischaemum muticum*, and herbs such as *Canavalia rosea*, *Desmodium umbellatum*, *Vigna marina*, *Crotalaria striata* and *Calopogonium mucunoides*.

Barringtonia formation: This formation occurs behind the *pes-caprae* formation. Common tree species are *Barringtonia asiatica*, *Cerbera odollam*, *Terminalia cattapa*, *Artocarpus altilis*, *Morinda citrifolia*, *Erythrina variegata*, *Hibiscus tiliaceus*, *Hernandia peltata* and *Casuarina equisetifolia*. Shrub species include *Pluchea indica*, *Desmodium umbellatum*, *Sophora tomentosa*, *Pemphis acidula* and *Ximenia americana*.

The vegetation of coral islands is essentially the same as strand vegetation of beaches and dunes. In the Indo-Pacific region, herbaceous cover of creeping plants of *Ipomoea pes-caprae*, *Canavalia rosea* and *Wedelia biflora* are found, including sedges and grasses at the high tide level (Mueller-Dombois & Fosberg, 1998; Jagtap & Untawale, 1999). Further inland, shrubs of *Scaevola taccada*, *Pandanus tectorius*, *Pandanus odoratissimus, Pemphis acidula*, *Hibiscus tiliaceus* and *Thespesia populnea*, occur alongside trees of *Barringtonia asiatica*, *Terminala cattapa*, *Calophyllum inophyllum*, *Casuarina equisetifolia* and *Pongamia pinnata*.

Uses and Users

Mangroves are important ecosystems that provide a wide range of goods and services to human communities living in coastal areas. The array of benefits derived from mangroves includes wood and non-wood forest products, fisheries, recreation, ecotourism, bio-filtration, coastal protection, and carbon storage and sequestration (Spalding et al., 2010).

Human uses of mangrove resources have been categorised into traditional, commercial and destructive uses (Field, 1995). Uses of mangroves can be direct, involving the tangible benefits of mangrove forest products and mangrove-associated fisheries, or indirect, involving the intangible benefits of ecosystem services (e.g. Saenger et al., 1983; Ewel et al., 1998; Hogarth, 2007; Walters et al., 2008). The former would entail the direct use of products from the ecosystem and the latter would rely on the use of the mangrove ecosystem as a whole (Bandaranayake, 1998).

Different mangrove species have different wood and bark properties, making some more suitable than others for specific uses (FAO, 1994). For example, genera such as *Rhizophora*, *Bruguiera* and *Ceriops* are characterised by their heavy hardwood and tannin-rich bark. As such, they are widely valued for construction, fuel wood and tannin extraction (Ewel et al., 1998). Their wood is not suitable for lumber or furniture making because of its tendency to split.

The majority of people living in mangrove areas are fishermen, deriving their livelihood from fishing and related activities (Walters et al., 2008). Harvesting and processing of mangrove wood is a full-time occupation for the minority living near mangrove areas. In many countries, local communities rely on mangrove forest products to meet their subsistence needs for fuel and construction.

Harvest for fuel wood is often non-selective with some species better for making charcoal (Walters et al., 2008). Often, people will harvest mangrove trees for fuel wood based on their availability rather than species preference. Due to the widespread dependence of coastal communities on mangrove wood products for subsistence needs, users will harvest what is most readily available to them (Ewel et al., 1998).

The impact of mangrove resource use by local villages can be sustainable as it forms an integral part of the ecology and functioning of the ecosystem (Spalding et al., 2010). However, with population growth and increasing demand, most mangrove forests are showing various levels of degradation due to over-harvesting of forest products. In recent decades, large-scale commercial and destructive uses have led to the loss of mangrove forests.

Wood Products

One of the most common uses of mangroves is as a source of wood (e.g. Ewel et al., 1998; Spalding, 2004; Walters et al., 2008; Spalding et al., 2010). The two most widespread uses of mangrove wood are for fuel and construction. In the Indo-West Pacific region, tree species, notably those of the family Rhizophoraceae, produce heavy hardwood that burns with a high calorific value. The wood is therefore highly suitable as fuel wood or for making charcoal. In the Atlantic East Pacific region, species of other families such as Avicenniaceae, Combretaceae and Pellicieraceae are also used. The harvest of mangroves for fuel wood is widespread throughout the tropics. Coastal communities in many tropical countries continue to rely heavily on mangrove wood for domestic consumption, and commercial markets for mangrove fuel wood and charcoal are well established.

As mangrove wood is strong, durable and rot-resistant, they are well suited for construction purposes. The extraction of poles is mostly for the construction of houses and fishing stakes. Mangrove poles are in great demand as piles for building and road construction. When piled into the ground, they are extremely resistant to rot under subterranean anaerobic soil conditions. Mangrove timber is also used for the construction of houses and boats. In addition to wood for fuel and construction, mangrove wood has been an industrial source of pulp for manufacturing rayon, cellophane and paper.

Non-Wood Products

Mangroves are also an important resource for a wide range of non-wood forest products (e.g. Spalding, 2004; Walters et al., 2008; Spalding et al., 2010). The mangrove palm *Nypa fruticans* is commonly used for the production of thatch, beverage, sugar, alcohol and vinegar in Southeast Asia. Production of mangrove honey is an important economic activity in countries such as Bangladesh, Vietnam, Cuba and Guyana. Mangrove foliage is used as fodder for camels and cattle, notably in Pakistan, the Middle East and India. Harvesting of mangrove bark for tannin as dye remains a viable economic activity in countries of the Asia-Pacific region. Mangrove species with medicinal properties are also harvested as herbal remedies by coastal communities in some countries.

Case Studies

In this book, the traditional and recent uses of mangrove and other coastal plants are categorised as wood or non-wood products (Table 1.4). All traditional and recent uses of wood and non-wood products in different regions of the world (Table 1.5) are substantiated by case studies. Case studies on wood products are described in Chapters 2 and 3 while those on non-wood products are described in Chapters 4 and 5. A total of 72 case studies have been described and their breakdown by the different regions is shown in Table 1.6. The status of all plant species mentioned in the case studies is listed in Table 1.7. They are differentiated as true mangrove species, mangrove associates and other species.

Table 1.4 Summary of uses of mangrove and other coastal plants, and their products

Use	Wood product	Non-wood product
Traditional	Fuel wood	Thatches
	Charcoal	Cigarette wrappers
	Poles	Sugar, wine and vinegar
	House construction	Foods and beverages
	Boat and canoe building	Wine additives
	Fishing stakes	Dyes and tannins
	Shrimp and fish traps	Fodder and forage
	Wood carvings	Honey and wax
	Decorative wood	Handicrafts
	Wood ash	Garlands and leis
	Charcoal ash	Brush and fern parks
		Fish poisons
Recent	Woodchips	Herbal remedies
	Pulp and paper	Vegetable supports
	Wood vinegar	Hedges and bio-fences
	White charcoal	Ornaments and souvenirs
	Briquettes	Fodder for dairy cattle
		Hides for duck hunters

Table 1.5 Useful products from mangrove and other coastal plants in different regions of the world

Product	Region 1	2	3	4	5	6	7	8	9	10
Traditional wood products										
Fuel wood	•	•	•	•			•	•	•	•
Charcoal	•			•				•	•	
Poles	•		•	•			•	•	•	•
House construction	•		•	•			•	•	•	
Boat and canoe building	•						•			
Fishing stakes	•			•			•			•
Wood carvings				•			•			
Decorative wood				•						
Wood ash										•
Charcoal ash				•						
Recent wood products										
Woodchips				•						
Pulp and paper			•							
Wood vinegar				•						
White charcoal				•						
Briquettes				•						
Traditional non-wood products										
Thatches			•	•			•		•	
Cigarette wrappers				•			•			
Sugar, wine and vinegar			•	•						
Foods and beverages	•		•	•			•			
Wine additives				•					•	
Dyes and tannins			•	•	•		•	•	•	
Fodder and forage		•	•							
Honey and wax			•	•	•			•	•	
Handicrafts and garlands			•	•			•			
Brush and fern parks			•							•
Fish poisons			•	•			•			
Recent non-wood products										
Herbal remedies			•	•				•		
Vegetable supports				•						
Hedges and bio-fences		•	•			•				
Ornaments and souvenirs			•		•		•			
Fodder for dairy cattle						•				
Hides for hunters						•				
Total	**7**	**3**	**16**	**23**	**3**	**3**	**13**	**7**	**8**	**5**

1. East Africa
2. Middle East
3. South Asia
4. Southeast Asia
5. East Asia
6. Australasia
7. Pacific Ocean
8. North and Central America
9. South America
10. West and Central Africa

Regions are based on the *World Atlas of Mangroves* (Spalding et al., 2010).

Table 1.6 Breakdown of case studies on wood and non-wood products by the different regions of the world

Region	Case study Wood	Non-wood	Total
East Africa	3	–	3
Middle East	–	1	1
South Asia	1	12	13
Southeast Asia	14	16	30
East Asia	–	3	3
Australasia	–	2	2
Pacific Ocean	2	9	11
North and Central America	–	3	3
South America	–	2	2
West and Central Africa	2	1	3
Asia Pacific	–	1	1
Total	**22**	**50**	**72**

Regions are based on the *World Atlas of Mangroves* (Spalding et al., 2010), with the exception of Asia Pacific.

Table 1.7 Status of plant species mentioned in the case studies

True mangrove species		Mangrove associate	Other species
Acanthus ebracteatus	*Nypa fruticans*	*Barringtonia asiatica*	*Alstonia spatulata*
Acanthus ilicifolius	*Rhizophora x annamalayana*	*Barringtonia racemosa*	*Anacardium occidentale*
Acrostichum aureum	*Rhizophora apiculata*	*Calophyllum inophyllum*	*Broussonetia papyrifera*
Acrostichum speciosum	*Rhizophora x lamarckii*	*Cerbera manghas*	*Camellia sinensis*
Aegiceras corniculatum	*Rhizophora mangle*	*Cordia subcordata*	*Garcinia subelliptica*
Avicennia germinans	*Rhizophora mucronata*	*Derris elliptica*	*Pandanus amaryllifolius*
Avicennia marina	*Rhizophora racemosa*	*Derris trifoliata*	*Polygonum tinctorium*
Bruguiera cylindrica	*Rhizophora stylosa*	*Heritiera fomes*	
Bruguiera gymnorhiza	*Sonneratia alba*	*Heritiera littoralis*	
Bruguiera parviflora	*Sonneratia apetala*	*Hibiscus tiliaceus*	
Bruguiera sexangula	*Sonneratia caseolaris*	*Instia bijuga*	
Ceriops decandra	*Xylocarpus granatum*	*Oncosperma tigillarium*	
Ceriops tagal	*Xylocarpus moluccensis*	*Pandanus odoratissimus*	
Conocarpus erectus		*Pandanus tectorius*	
Excoecaria agallocha		*Phoenix paludosa*	
Kandelia candel		*Pluchea indica*	
Laguncularia racemosa		*Sesuvium portulacastrum*	
Lumnitzera littorea		*Tacca leontopetaloides*	
Lumnitzera racemosa		*Thespesia populnea*	


Photo: H.T. Chan

Chapter 2

TRADITIONAL WOOD PRODUCTS

Fuel Wood

Wood for charcoal production, Malaysia

The exploitation of timber for fuel wood in the Matang mangrove started in 1930 with the introduction of charcoal kilns (Azahar & Nik Mohd Shah, 2003; Amir, 2005). Since then, charcoal production remains the most important use of mangrove wood. There are at present, 86 registered charcoal contractors in Matang with a total allocation of about 9,500 hectares of charcoal coupes. Each charcoal contractor is usually allocated a felling area about 10 hectares annually.

Tree felling and extraction procedures in the Matang mangrove have been previously described by Chan (1986) and Chan & Salleh (1987). For a given felling area, the entire felling operation is done by a team of 4–5 workers. The contractor rarely exercises direct supervision though he may occasionally visit the working area. The work is entrusted to a headman who is responsible for constructing the barrack, proper division of working areas and the general welfare of the workers.

The barrack for workers is a temporary shelter made of mangrove poles and *Nypa* thatches with cooking and accommodation facilities. It is often located by the bank of a creek to facilitate the use of the creek water for washing and bathing. Potable water is dependent on rainwater, which is channelled from the roof into tanks. However, during the dry season, potable water has to be brought in by boat. When the barrack is completed, the workers would then proceed to prepare their individual stacking platforms within their designated working areas along the riverbank where the transport boat can come alongside during high tide. The next step is to lay their respective extraction tracks. This is done by cutting trees and bucking them into billets of lengths required for charcoal manufacture. The billets are then laid parallel to each other at regular intervals and sawn timber planks are placed over them forming a single track. Actual felling then commences with the cutting of trees beside the track using a chain saw. When sufficient trees (usually about 10 per day) are cut, they are bucked into billets of 1.6 m length.

Following bucking, the billets are debarked by knocking off the bark using a wooden mallet. The debarked billets are later loaded onto a wheelbarrow and pushed along the wooden track to the stacking platform by the riverbank. To assist in the lifting and balancing of the wheelbarrow while pushing a full load, a strap is sometimes used. Its ends are looped to each handle of the wheelbarrow while it is placed over the neck. Normally, a worker takes two days to load up a boat capable of carrying 150 billets.

In Matang, the mangrove billets from the forest are transported to the charcoal factories to be processed into charcoal. Elsewhere in Malaysia, the billets are split into sections and sold as firewood. With high calorific value, mangrove firewood is in demand for specialised cooking such as roasting of pigs.

Photos: Hung Tuck Chan

Debarked mangrove billets are loaded onto a wheelbarrow and pushed along a wooden track to the stacking platform by the riverbank (top), mangrove billets at the charcoal factory site (bottom right), and stacks of split mangrove wood are sun-dried before they are sold as firewood (bottom left).

Wood for roasting, Micronesia

Kosrae is one of the four islands of the Federated States of Micronesia in the Pacific. The other islands are Pohnpei, Chuuk and Yap. The 112 km^2 island of Kosrae has a human population of 8,000 and over one-third of the households use wood from the mangroves for cooking (Allen et al., 2001; Naylor et al., 2002). Mangroves of Kosrae cover 1,560 hectares or 14% of the total land area and occupy about two-thirds of the shoreline. The two species extracted primarily for fuel wood are *Rhizophora apiculata* and *Bruguiera gymnorhiza*. The wood of *Rhizophora apiculata* is particularly favoured because it is exceptionally hard and burns long, generating much heat and producing little smoke. In general, the harvesting and extraction of mangrove trees in Kosrae are inefficient as less than half the total volume of trees cut is taken out of the forest.

Mangrove forests constitute public land in Kosrae (Naylor & Drew, 1998; Naylor et al., 2002). The local people have free access to the mangroves for collecting fuel wood and there are no restrictions or fees for fishing or hunting. As a result, extraction of fuel wood for domestic use and for sale in the local market is fairly rampant. Almost 90% of households surveyed in the villages of Lelu, Malem, Utwe, Tafunsak and Walung use mangrove wood for cooking, and almost one-third relies on mangrove wood as their primary source of cooking fuel. One-quarter of the households uses mangrove wood for cooking three times a day, and another one-third uses mangrove wood twice a day.

In addition to the daily use for cooking, many households in Kosrae use mangrove wood for *uhms*, a type of earthen oven consisting of rocks piled among a stack of burning mangrove wood (Naylor & Drew, 1998; Allen et al., 2001; Naylor et al., 2002). *Uhms* are used throughout the island during festivals and ceremonies. Households in Utwe and Walung use significantly more mangrove wood for *uhms* than the other villages because of their proximity to mangrove forests. Daily cooking accounted for 67% of mangrove wood use, and *uhm* cooking accounted for the remaining 33%. Based on the use for cooking, which is by far the predominant use of mangrove wood on the island, the gross value of wood consumed is about 3.5% of the mean annual household income.


Photos: Dana Lee Ling

An *uhm* is ignited with mangrove wood (left) and a boar is roasted (right).

Of the cultural ceremonies in Kosrae, funerals are the most important and they come with enormous feasts (Cook, 2010). Guests are served with roast pig, fried chicken, rice, fish, breadfruit, taro and coconut. Preparing the pig takes longest time and roasting is done over an *uhm*. Basalt rocks are stacked over burning mangrove wood and when heated up, the pig is roasted. Every guest attending the funeral, no matter the relation to the deceased, will receive meals as long as he or she remains at the funeral.

Wood for fish smoking, Cameroon

In Cameroon, smoking is a popular method of fish preservation. Felling of *Rhizophora racemosa* trees is an important economic activity, with most of the wood harvested used for fish smoking (Ajonina & Usongo, 2001; Feka et al., 2008, 2009). Other mangroves species such as *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erectus* are also used (Atheull et al., 2009).

For fish smoking, mangrove wood is preferred because of its high calorific value and its combustion imparts a golden brown colour to the smoked fish, enhancing their marketability (Feka et al., 2008). In addition, smoke from burning mangrove wood has antimicrobial properties. Ethanol extract of smoke from *Avicennia germinans* inhibited the growth of bacteria (*Escherichia coli and Staphylococcus aureus)* and yeast (*Saccharomyces cerevisiae)* (Asita & Campbell, 1990). Smoke from *Rhizophora racemosa* inhibited *Staphylococcus aureus* and *Saccharomyces cerevisiae.*


Photos: Longonje Ngomba

A *Nypa* thatched hut (left) and smoked fish for sale (right) in Cameroon.

Fish smoking is done exclusively by women, aided by their children or paid assistants, and is carried out in open *Nypa* thatched huts (Feka et al., 2008). Fishmongers from various areas around Cameroon, and neighbouring Nigeria and Gabon, would purchase the smoked fish for subsequent retailing.

Large quantity of wood is used for fish smoking, chiefly due to the low fuel efficiency of the traditional smoke system (Feka et al., 2008, 2009). With the introduction of the improved smoke system, wood consumption is reduced by half and smoking time by 65%. It produces high-quality smoked fish, and reduces the incidence of smoke-related diseases in women and children involved in fish smoking. The improved smoke system was first developed by the Food and Agriculture Organization of the United Nations (FAO), and the Food Research Institute of the Council of Scientific and Industrial Research (CSIR) in Ghana (FAO, 1986).

Charcoal

Charcoal production, Malaysia

In Matang, Malaysia, the manufacture of charcoal from *Rhizophora* wood remains the most important forest industry (Azahar & Nik Mohd Shah, 2003; Amir, 2005; MTC, 2009). There are at present 86 registered charcoal contractors and 348 kilns in operation. In 2012, new licenses have been issued to 19 contractors to operate another 140 kilns (Boon Keong Gan, pers. comm.). *Rhizophora apiculata* and *Rhizophora mucronata* are the two species used for commercial charcoal production.

Rhizophora apiculata (Rhizophoraceae) is a large-sized tree that grows up to 30 m tall with 50 cm trunk diameter. It has prop or stilt roots, looping from the base of the trunk, and occasionally has aerial roots emerging from the lower branches. The bark is grey with longitudinally fissures. Leaves are simple, opposite and elliptic with fine black dots on the underside. The inflorescence is axillary and typically two-flowered. The peduncle is stout and the calyx is four-lobed, greenish-yellow inside and reddish-green outside. Petals are four and white. Hypocotyls are 25–30 cm long, greenish-brown and relatively smooth. Mature propagules have a red collar. [Sources: Selvam, 2007; Giesen et al., 2007]

Rhizophora mucronata (Rhizophoraceae) is a tree 25–30 m in height. Trees are characterised by prop or stilt roots. The bark is dark grey and horizontally fissured. Leaves are single, opposite, large, leathery, broadly elliptic to oblong with clear black dots on the under surface. The inflorescence is axillary and dichotomously branched with 4–8 flowers. The peduncle is slender, yellow and 2–3 cm long. Flowers are creamy white and fragrant. Calyx is four-lobed and pale yellow. Petals are four in number, light yellowish with dense hairs along the margin. Hypocotyls are 50–70 cm long, cylindrical, warty and yellowish-green. Mature propagules have a yellowish collar. The species grows well along the banks of tidal creeks in deep soft mud. [Sources: Selvam, 2007; Chan & Baba, 2009]

Photos: Hung Tuck Chan

Bark of *Rhizophora apiculata* (left) and *Rhizophora mucronata* (right).

Wood of *Rhizophora apiculata* and *Rhizophora mucronata* has densities of 890 and 900 kg/m^3, and calorific values of 18.5 and 18.0 MJ/kg, respectively (Baharudin & Hoi, 1987). The physical properties and calorific values of the wood of both species are therefore comparable. It has been reported that the calorific value of five tonnes of *Rhizophora mucronata* wood equals that of 2–3 tonnes of coal (ACTI, 1980).

Charcoal factories in Matang are usually constructed close to rivers or canals where transport boats can dock (Chan, 1986; Chan & Salleh, 1987). The factories are made of sawn timber, mangrove poles and *Nypa* thatches, and they each house a row of 10–12 kilns. The type of charcoal kiln presently used is the Siamese beehive kiln, which was first introduced to Matang in 1930 by charcoal manufacturers from southern Thailand (Amir, 2005).

The kiln, a dome-shaped structure resembling an igloo, is made of bricks, sand and clay. There are four equidistant smoke vents in the vertical wall and there is a door, which enables access to the kiln. Costing USD 5,000–6,000 to construct, the average life of a kiln is about 7–10 years, if constructed on firm ground and regularly used. Each kiln measures 6.7 m in diameter and 7.1 m in height. Each burn requires a charge of 40 tonnes of greenwood, yielding 10 tonnes of charcoal. Kilns are normally operational nine times a year, each requiring timber from 2.8 hectares of forest.

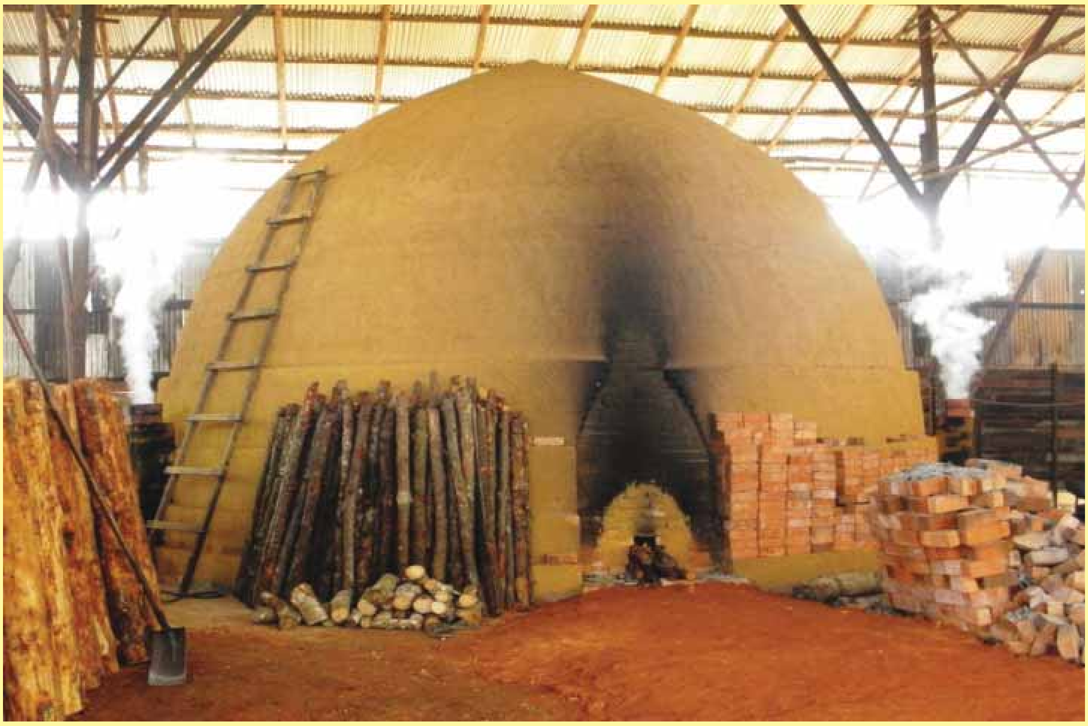


Photo: Hung Tuck Chan

A typical beehive charcoal kiln in Matang.

On arrival of the boat, mangrove billets are unloaded and stacked outside the factory (Chan, 1986; Chan & Salleh, 1987). If debarking is not done in the forest, charcoal producers would employ workers to debark the billets. After debarking, which yields better charcoal conversion, the billets are shoulder carried into the kiln and filled by vertical close packing. The bottom ends of each billet are placed over a piece of brick to ensure complete carbonisation at the ground level. Only the base of the kiln is packed, leaving the upper portion of the dome empty. When the kiln is loaded, the entrance door is sealed to form a firing port at the bottom. Normally, small diameter mangrove billets (less than 10 cm) are used for firing. Due to the increasing difficulty in obtaining adequate supply, some operators have started to use rubber wood or timber off-cuts, purchased from nearby sawmills.

Photos: Hung Tuck Chan

Mangrove billets outside the charcoal factory (top left), debarking billets (top right), firing schedule Stage I (bottom right) and firing schedule Stage II (bottom left).

The firing schedule is in three major stages (Loo, 2008). Stage I involves the burning of wood at 100–120ºC for 8–10 days. Stage II is characterised by a higher temperature of 250ºC. At this stage, the kiln entrance is partially sealed, preventing complete combustion of wood. This carbonisation stage takes about 12–14 days. During Stage III, the charcoal is left to cool for 8–9 days. The kiln entrance and smoke vents are completely sealed at this stage. The whole process of charcoal production takes about 28–30 days. The timing of each stage is determined by a headman who is guided by the colour and odour of the smoke emitted from the vents.

The present market value of high-grade charcoal is about USD 200 per tonne (Azahar & Nik Mohd Shah, 2003). Some 30% of the charcoal produced from Matang is exported to Japan. Two local incorporated Japanese companies are involved in purchasing, grading and packing the charcoal for export to Japan. Charcoal from Matang has set an international benchmark for quality and attracts premium prices (Neilson, 2011). The Matang charcoal is smokeless and burns three times longer. In Japanese homes, the high-grade charcoal is used for barbecuing and tea-making, and as natural deodoriser and water purifier.

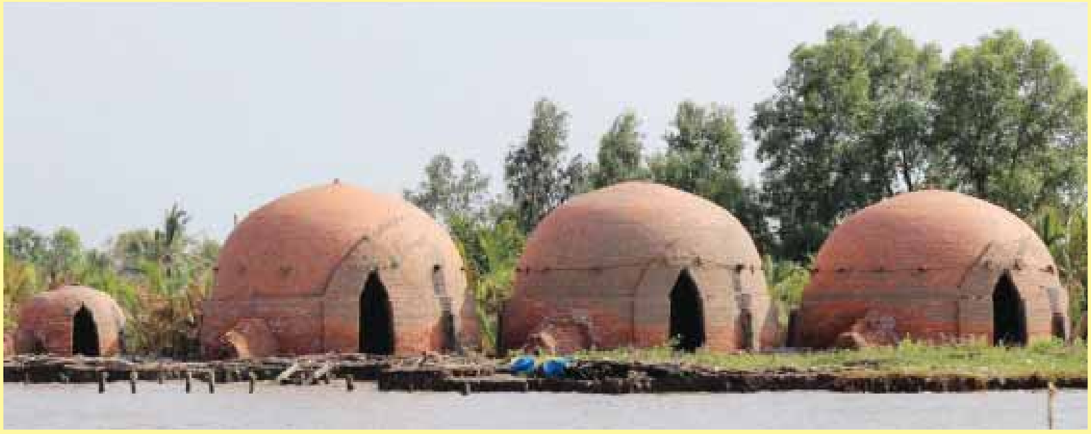
Photos: Hung Tuck Chan

High-grade charcoal from Matang is packed for export (top row). Medium to lower grade charcoal (bottom row) is packed for the local market.

Charcoal production, Vietnam

In Ca Mau at the southernmost tip of Vietnam, mangroves are a major source of timber and thatching for houses and other buildings (Clough et al., 2002). They also provide the local communities with fuel wood for cooking. Yield of wood was estimated to be 30, 44 and 180 m^3 per hectare for mangrove plantations 10, 20 and 30 years of age, respectively.

Trees of *Rhizophora apiculata* and *Bruguiera parviflora* are the main species converted into charcoal (Hong & San, 1993). Charcoal kilns are dome-shaped with a vertical wall. Each kilns measures 6–7 m in diameter and 2.8–3.0 m in height, and are made of bricks, sand and clay. There are 4–5 smoke vents in the vertical wall, an arched door for access and an extended tunnel for firing. Each kiln can accommodate 30–35 m^3 of wood. Loading by six workers requires two days before the access door is sealed. The kilns are housed in long barracks with living quarters and cooking facilities for workers. Made of mangrove poles and *Nypa* thatch, the barracks are located along riverbanks for convenient transportation, and supply of water for washing and bathing. Mangrove billets (1.4–1.6 m in length) are loaded vertically or horizontally into the kiln, before the door is sealed. The carbonising process usually takes 22–26 days with 12–14 days of firing and 10–12 days of cooling. The timing of each stage is determined by a skilled operator who monitors the process by the colour and smell of the smoke emitting from the vents. After each burn, the charcoal is unload, weighed and transported by boat to the depot.



Photos: Vien Ngoc Nam

Charcoal barracks (top) and new kilns along riverbanks in Ca Mau (bottom).

In Can Gio, 65 km south of Hochiminh City, the manufacturing of charcoal from mangrove wood is a recent activity (FAO, 1993). The six charcoal kilns in operation are of the brick beehive type, 3 m in height and 6 m in diameter at the base. They are made of bricks plastered with a mortar mixture of sand and clay, each with four equidistant smoke vents and an arched door. Its expected lifespan is 15–20 years and loading capacity is 27 tonnes or 45 m^3 of wood. Only wood from the second and third thinning operations of mangrove plantations can be used for charcoal making. Billets of *Rhizophora* (1 m long and 6–10 cm in diameter) are loaded vertically over a layer of billets that are horizontally stacked to ensure complete carbonisation. When loading is completed, the door of the kiln is partially sealed, leaving a small aperture for firing.

Direct and indirect firing are the two methods of carbonisation adopted. In direct firing, fire is ignited inside the firing port located at the kiln wall. The duration of burning is shorter but charcoal yield and quality is lower. In indirect firing, the firing port is extended 1.0–1.2 m from the kiln wall and combustion heat is drawn into the kiln. Requiring a longer firing period, this method produces charcoal of better quality and higher yield. Taking 20–25 days to complete, each charge produces six tonnes of charcoal with a conversion efficiency of 22% and 25% for direct and indirect firing, respectively.

Photos: Vien Ngoc Nam

Dome-shaped charcoal kiln in Ca Mau with vertical wall, arched access door and extended firing tunnel (top left), smoke emitting from one of the vents (top right), *Nypa* thatches are used as roofing for charcoal kiln barracks (bottom right), and unloading fuel wood for firing the charcoal kilns in Ca Mau (bottom left).

In Dong Nai, 70 km northeast of Hochiminh City, charcoal kilns are structurally different as they are located outside the mangrove area (Vien Ngoc Nam, pers. comm.). The top half of the kiln is constructed above the ground while the bottom half is constructed below ground. There are two types of kiln, namely, brick kilns made of bricks, clay and sand, and clay kilns made of clay and sand. The kilns are each housed beneath shelters of mangrove poles and *Nypa* thatches. Each kiln has an access door for loading wood and unloading charcoal. At the opposite side of the door is a unique subterranean firing port, which is located a short distance from the kiln and 2 m below ground. Mangrove billets of *Rhizophora* are stacked horizontally into the kiln and each burn takes 30 days with a cooling period of another 12 days. Under-sized mangrove billets are used to ignite the kilns. Wood of *Anacardium occidentale* (cashew nut) is also used.

Photo: Vien Ngoc Nam

A general view of a charcoal factory in Dong Nai.

Photos: Vien Ngoc Nam

Charcoal kilns in Dong Nai are individually housed beneath *Nypa* shelters (top left), subterranean firing port of the charcoal kiln (top right), loading fuel wood into a brick kiln (bottom right) and a clay kiln (bottom left).

Mangrove charcoal in Vietnam has a great variety of uses including domestic cooking, pig roasting and tea drying (FAO, 1993). The chemical and metal industries as well as the street food vendors are also major users of charcoal.

Poles

Rhizophora poles, Malaysia

In the Matang mangrove, Malaysia, intermediate felling (thinning) for poles has been traditionally carried out since 1930 in 15- and 20-year-old forest stands. There are about 70 registered pole contractors in Matang and the total area allocated for Thinning I and II was 16,300 hectares from 2000–2009 (Azahar & Nik Mohd Shah, 2003). Normally, a pole contractor is allocated a forest area for Thinning I and another for Thinning II in a year, each of which is about 16 ha in area. An average of 3,000–4,000 and 1,000–2,000 pieces of poles can be obtained from each of the two allocated areas, respectively. The number of standing residual trees following Thinning I and II has been estimated to be 3,400 and 1,600 trees per hectare, respectively.

The stick thinning operations in Matang have been described by Chan (1986) and Chan & Salleh (1987). For a given area, usually 3–4 workers are employed by the contractor to carry out the felling and extraction of poles. A headman is usually appointed to ensure systematic felling and fair allocation of individual working areas. The felling of *Rhizophora* trees for poles is done using an axe, starting from the riverbank and progressively working inland. The process involves selecting a well-formed tree and a stick is used to determine which are the trees to be felled. Trees within the stick radius, with a selected tree as the centre, are felled. This is then repeated. The stick lengths from Thinning I and II are 1.2 and 1.8 m, respectively. The felled trees (8–13 cm diameter) are then bucked into 5.0, 5.5 and 6.0 m lengths, using the axe as a measuring tool. The poles are then shoulder carried individually to the riverbank where they are stacked, awaiting boat transport to the jetty. Often, the workers construct extraction tracks for carrying out the poles by laying 2–3 poles joint end to end. The workers are paid based on the number of poles stacked at the riverbank. In thinning operations, it is not uncommon to find inland areas inadequately thinned. This is particularly so when shoulder carrying becomes increasingly tedious and when there is a need for transporting the poles using a small rowing boat to the main stacking area. The additional work of loading and unloading often deter workers from working in such areas even when extracting such poles fetches higher wages.

A worker can cut and transport about 30–40 pieces of poles per day. In a month, he normally works for only 15–20 days since the boat is only able to dock at the stacking site during periods of high water. For nearby felling areas, the workers commute daily while for distant areas, they have to seek accommodation in temporary shelters at the felling site. When sufficient poles have been stacked at the riverbank, they are transported to the jetty by boats with a loading capacity of 200–300 pieces of poles. At the jetty, the poles are tagged and graded based on their length, straightness and diameter size. With the rapid development in housing and road building, mangrove poles are in great demand for piling purposes. Poles are also used as stakes for fish traps and as decorative panels of seafood restaurants in the coastal areas.

Photos: Hung Tuck Chan

Stick thinning of mangrove poles (top left), poles are stacked at the riverbank (top right), poles are graded at the jetty (bottom right), and poles are used as decorative panel (bottom left).

Oncosperma poles, Malaysia

At the landward side of mangroves in Malaysia where *Oncosperma tigillarium* palm (*nibong*) is found, its exploitation for poles remains an important industry (Chan & Salleh, 1987). The palm grows in clumps, occasionally in gregarious stands.

Oncosperma tigillarium (Palmae) is a tall slender palm growing in clumps at the landward mangrove fringes and up to 25 m tall. Stems are rarely more than 10 cm in diameter. Spines (7–8 cm long) stick stiffly at right angles from the stems. The leaf stalk is brown, scaly and thorny. Leaves are pointed, greyish-green and strongly drooping, which enables them to quiver in the breeze. Flowers occurring in clusters are bisexual, located below the crown, up to 60 cm long and branched. Fruits are round and dark green, turning dark purple when mature. [Sources: Tomlinson, 1986; Chan & Salleh, 1987; Giesen et al., 2007]

Photo: Sabah Forestry Department

Photo: Hung Tuck Chan

An aerial view of a pure *Oncosperma tigillarium* forest (top left), wild cluster of the palm (bottom left), and planted cluster with slender stems and drooping leaves (right).

An interesting account of the felling of *nibong* trees at the Jugra Forest Reserve in Selangor was given by Chan & Salleh (1987). The operation is carried out by a team of 8–10 workers with a headman who is responsible for the efficiency of the operation and the safety of the individual workers. Before commencement of tree felling, it is customary for the workers to erect an altar to appease the spirits of the forest so that extraction can be safely and smoothly carried out. Only after paying respect to the spirits that reign in the forest will the workers commence the logging operation.

Nibong trees (greater than 13 cm diameter) are felled using an axe and bucked into lengths of 6, 12 or 18 m (Chan & Salleh, 1987). The spiny thorns are removed using a knife. The poles are then hauled onto a 6 m long boat-like sledge (*ongkak*). The *ongkak* consists of a pair of keels (each made from a sliced piece of *nibong* trunk), which are bound by wooden cross-pieces and wires. Two light wooden blocks are placed onto the two end cross-pieces. They serve as platforms for the *nibong* poles. Usually four workers are required to pull and push the *ongkak* (two in the middle, one in the front and one at the back) and only four pieces of *nibong* poles can be hauled out at a time. Pulling is done using ropes, which are looped around the shoulders of each worker. To ease the laborious task of hauling the heavy load, the *ongkak* is pulled over a slide-way made by laying round sleepers over longitudinal runners along slots. The sleepers are each lubricated with lard to permit smooth hauling. On approaching the riverbank, sliding of the *ongkak* ceases and the *nibong* poles are then pushed into an extraction canal for subsequent hauling to the main stacking site during high tide. At the stacking site, the poles are loaded onto boats and transported to the jetties of nearby towns for further distribution. A boat can load up to 60 pieces of poles.

Nibong poles are utilised largely for structural purposes in view of their reputed durability. The timber is hard and resistant to seawater, wood borers and termites (Giesen et al., 2007). They are not susceptible to marine borers. Round poles, with their basal ends sharpened, are used as house and jetty posts, fish traps and boat-docking stakes (Chan & Salleh, 1987). The lifespan of *nibong* poles used as stakes can be prolonged by excavating the core of the projected end and filling it with salt and subsequently covering it with an inverted tin can. This is to ensure that the core will not rot away with the absorption of rainwater. Well-preserved poles can last over 10 years under partial seawater submersion. When used as structural supports and components of houses, they can last 40–50 years.

Photos: Hung Tuck Chan

Close-up of an *Oncosperma tigillarium* pole (top left), basal ends of poles are sharpened when used as stakes (top right) and fishing boats docked in the mangrove using *nibong* poles (bottom).

Wood from the lower part of *nibong* pole possesses greater mechanical strength due to greater specific gravity and higher percentage of vascular bundles (Laemsak, 1991; Hanvongjirawat, 1992). The core zone consists of parenchyma tissue and thin-walled fibres while the peripheral zone comprises sclerenchyma tissue and thick-walled fibres of poly-lamellate structure.

Split sections of poles are used as house floorings and fish-drying platforms. *Nibong* floorings have high abrasive resistance, superior strength properties and are suitable for light to medium floor traffic (Mohmod & Md Tahir, 1990).

Wood for Construction

Boat building, East Africa

In Kenya, Madagascar and Zanzibar, the fishing communities are renowned for their boat building skills. Simple dug-out canoes, with or without stabilisers, are carved from large trunks of *Avicennia marina* (Weiss, 1973; Wass, 1995; Rasolofo, 1997; Dahdouh-Guebas et al., 2000). The ribs and keels of larger vessels such as the traditional dhows are built from *Sonneratia alba*, *Heritiera littoralis* or *Avicennia marina*. Mangrove species such as *Rhizophora mucronata*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Lumnitzera racemosa*, *Xylocarpus moluccensis* and *Sonneratia alba* are used for masts, paddles and oars.

In Kenya and Zanzibar, the dhows continue to be the work-horses of the sea (Weiss, 1973; Vandenabeele, 2009). In the Lamu archipelago of Kenya, an estimated 30 *Swahili* master craftsmen still possess the technical skills to make these boats. They learnt the skill from the Arabs who were the master dhow builders and they are now teaching their sons the craftsmanship. The design has not changed over the years and the wind is still the power of choice. Planks are usually treated with shark oil to soften them and prevent splitting during bending. Sometimes, heating over a fire may be necessary.

In the Lamu archipelago, a *Swahili* boat builder can make one or two boats a year when working alone, and even three when he has assistance (Vandenabeele, 2009). It takes several months of hard work to build a boat, which has a lifespan of 40–50 years, if properly maintained. The launch of the boat is often celebrated with some festivity. Most of the dhows built are used to transport mangrove poles. The boat builders also make smaller vessels for fishing and more luxurious crafts for the tourism industry. In Lamu, 90% of the people at Faza and Kilitini depend on fishing, while marketing mangrove pole is the main occupation of the people at Mbwejul and Dau. However, the number of boats for transportation of mangrove poles and for fishing has hardly increased. Most of the boats are old crafts with replacement of parts.

House construction, Kenya

In Kenya, the most significant use of mangroves wood takes the form of poles for house construction (Dahdouh-Guebas et al., 2000). Poles of *Rhizophora mucronata*, *Ceriops tagal* and *Bruguiera gymnorhiza* are often used. Each of these species occupies a particular place within the framework of a house. The long and strong poles of *Bruguiera gymnorhiza* are used for the rooftops. *Rhizophora mucronata* poles are used for the walls, especially the thicker supportive poles and corner pillars. The thinner poles of *Ceriops tagal* are used to create an interweaving network for the walls. They are also used to construct structures such like shrines, cooking sheds and animal sheds.


Photos: Ruth Frost

Dhows of different shapes being built in the Lamu Archipelago, Kenya.

It is evident that the use of mangrove species in building the various components of the house is dependent on their size classes (Lang'at & Kairo, 2008). *Boriti* (12–14 cm in diameter) are thick poles that are piled into the ground and serve as main supports for the walls (Dahdouh-Guebas et al., 2000). At each side of the wall, they are intertwined by *fito* (3–4 cm in diameter). The walls are then filled with clay or coral rock. When plastered, the walls resemble those of a modern brick house. The ceiling is made of *boriti* (12–14 cm in diameter) and *nguzo* (14–20 cm in diameter). The roof comprises *pau* (4–8 cm in diameter) and *mazio* (8–12 cm in diameter). *Vigingi* (20–35 cm in diameter) is used to support the roof extension that forms the veranda of the main door. The roof is then thatched with dried woven coconut leaves (*makuti*). This material insulates the house from the hot sun. About 90% of the village houses are of the traditional design, with a bare instead of a cement floor. A house can last over 30 years, with an average lifespan of eight years, depending on the quality of poles and fillings used in the framework, and whether or not the house has a cement floor and plastered walls.

Wood Handicrafts

Mah Meri wood carvings, Malaysia

The *Mah Meri* people of Carey Island in Selangor, Malaysia, are an aboriginal community rich in culture and tradition (Maizura, 2006). They have lived on the island for the past 400 years and have settled in five villages. Residents of the village of Sungai Bumbun, with 500 residents, are well-known for their indigenous handicrafts (Rahim, 2007). While the women weave exquisite products, the men carve unique wooden sculptures and masks that have won international awards.

Photo: Joseph Lang'at

Boriti and *fito* poles used for construction of houses in Kenya.

Currently, there are about 30 wood carvers in Sungai Bumbun (Rahim, 2007; Ani, 2008). Sculptures are made from the wood of *Xylocarpus*. Its wood is favoured because of its attractive colour and appearance, and its fine texture contributes to the smoothness of the finished product. The cream-coloured sapwood can be easily distinguished from the reddish-brown heartwood. The wood of *Xylocarpus moluccensis* is preferred over that of *Xylocarpus granatum*. It has been reported that the wood of these two species is also used to produce carvings in Tonga, one of the Pacific Islands (Steele, 2006).

Xylocarpus moluccensis (Meliaceae) is a mangrove tree that grows up to 20 m in height. The tree has small buttresses, and produces many pointed, conical and saucer-shaped pneumatophores. Leaves are spirally arranged with 2–3 pairs of leaflets that are pointed at the apex. Flowers are borne in clusters. Calyx lobes are rounded and white while petals are yellowish. Fruits are round (6–11 cm in diameter), green when young and brown when ripe, bearing 5–10 seeds. This species can be distinguished from *Xylocarpus granatum* which produces leaves with rounded apex and large fruits (12–25 cm in diameter) resembling cannon balls. [Sources: Giesen et al., 2007; SFD, 2010]

Photo: Shigeyuki Baba

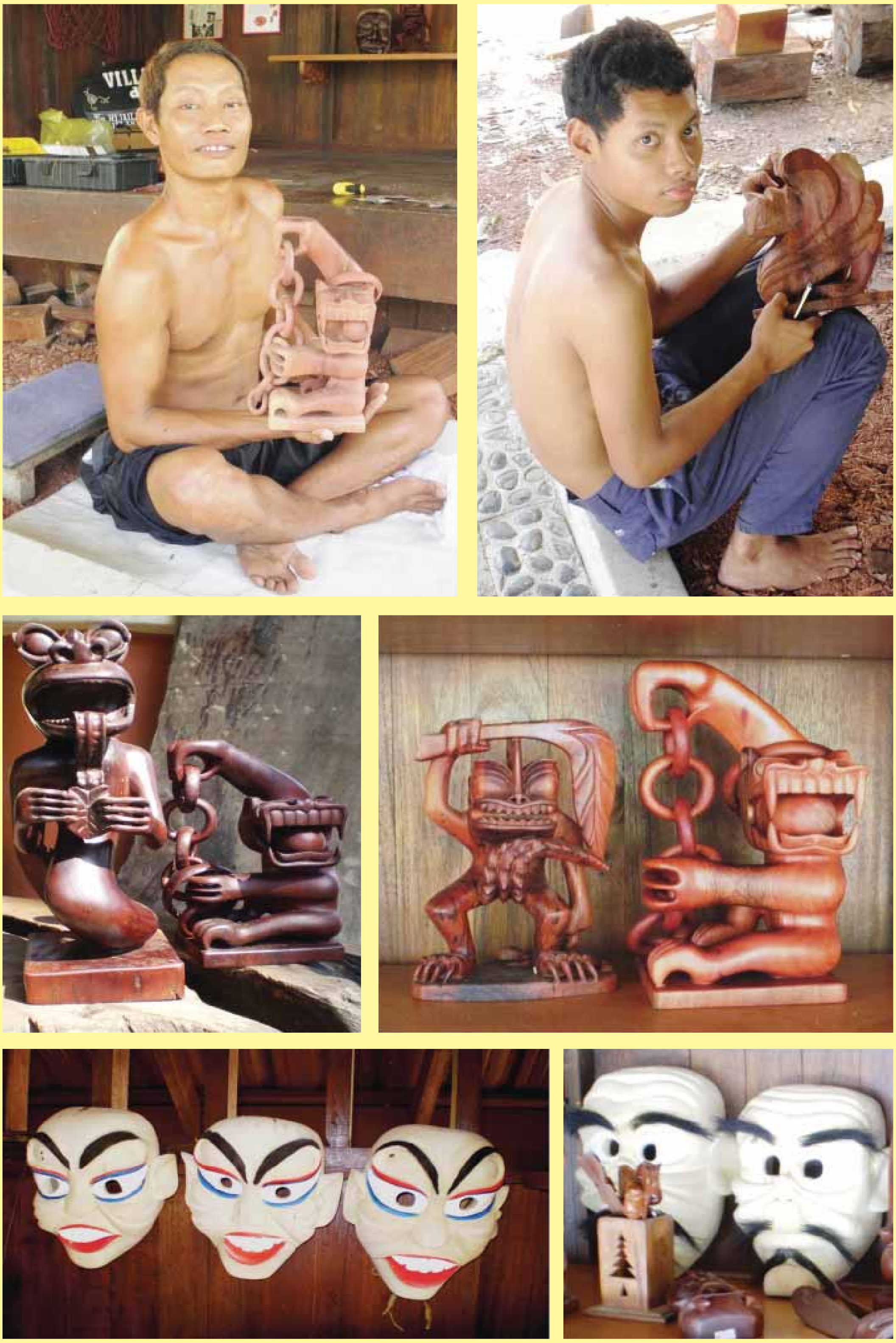
Photo: Hung Tuck Chan

Photos: Wood Explorer

Bark of *Xylocarpus moluccensis* (top left) and *Xylocarpus granatum* (top right), and wood panels of *Xylocarpus moluccensis* (bottom left) and *Alstonia spatulata* (bottom right).

As trees of these two species of *Xylocarpus* are getting scarce on the island, the Forestry Department has set aside an area of 10 hectares at the Jugra Forest Reserve for plantation establishment since 2007. Besides sculptures, the *Mah Meri* people also make masks from the wood of *Alstonia spatulata*, which is light, soft and easy to carve.

The sapwood of *Xylocarpus* is light yellow-brown, straw-coloured or light pink and contrasts sharply from the heartwood, which is light red to very dark red, sometimes streaked with darker colours. The timber is moderately hard and heavy, with density of 625–880 kg/m^3 air dry. Fairly durable under exposed conditions, the timber is used for carvings and ornamental items. It is very attractive and is suitable for high-class cabinet work, interior finishing, panelling, mouldings, partitioning, stair railings and shelves. [Source: Wong, 1982]



Photos: Hung Tuck Chan

Mah Meri father and son displaying their wood sculptures (top row), mystical and hauntingly beautiful sculptures carved from *Xylocarpus* wood (middle row), and colourful and enchanting masks carved from *Alstonia* wood (bottom row).

It takes up to a week to produce a mask and several months to complete a sculpture. Each piece of indigenous woodcraft tells a story passed down from generation to generation (Suhaimi, 2009). Taught from father to son, the wooden masks represent ancestor spirits, which they wear when performing traditional dances. The wooden sculptures are not for worship but rather a means of communicating with the ancestors. Mystical and hauntingly beautiful, the *Mah Meri* sculptures have been awarded the seals of excellence for quality and artistry by the United Nations Education, Scientific and Cultural Organization (UNESCO) and the ASEAN Handicraft Promotion and Development Association (Virtual Malaysia, 2005; Chan, 2010).

Craft wood, Pacific Islands

In the Pacific Islands, craft wood is derived from tree species associated with mangroves (Thaman et al., 2006). Of these species, the wood of *Instia bijuga* is most suitable for carving, and highly valued for making handicrafts, household utensils, drums and war clubs. It is considered the most valuable in Samoa. Kava bowls, made for ceremonial occasions and for sale to tourists, are typically made from this wood.

In Palau, the wood of *Calophyllum inophyllum* is much sought after for carving traditional story boards (Friday & Okano, 2006a). In the Cook Islands, the wood of *Cordia subcordata* is used for carving traditional figures and making musical instruments (Friday & Okano, 2006b). The beautiful wood of *Thespesia populnea* has been traditionally used for making bowls, utensils, jewellery boxes, furnitures, figurines and other craft items (Friday & Okano, 2006c). The moderately soft wood of *Hibiscus tiliaceus* is characterised by a white sapwood and dark greenish-brown heartwood (Elevitch & Tomson, 2006). The wood has been used occasionally for making carved bowls and bracelets with a marbled appearance.

Photo: Randolph Thaman

Photo: Hung Tuck Chan

Leaves of *Instia bijuga* (left), and leaves and fruits of *Calophyllum inophyllum* (right).

Decorative wood, Southeast Asia

When walking along a mangrove shore, we often encounter strange-looking tree stumps that have been abraded by the waves. Using them as driftwood for aquaria and ponds comes to our mind. Besides tree stumps, roots and pneumatophores of *Xylocarpus* and *Heritiera*, when processed, resemble fossil bones of animals. They can serve as decorative wood for indoor use.


Photos: Hung Tuck Chan



Photos: Shigeyuki Baba

Strange-looking mangrove tree stumps that can be used as driftwood for aquaria and ponds (top row), peg-like pneumatophores of *Heritiera fomes* (bottom left) and *Xylocarpus moluccensis* (bottom centre), and sinuous plank buttress of *Xylocarpus granatum* (bottom right).

Minor Wood Products

Wood ash, Nigeria

Wood ash from *Rhizophora racemosa* and *Avicennia germinans* has long been used in Nigeria and neighbouring countries in West Africa (Loto & Fakankun, 1989). The solution from wood ash (*odoro*) has very wide application in the cooking of food such as yam, plantain and bean. It gives added taste to the food, aids in softening the food and accelerates the cooking time.

Salt is extracted from roots of *Rhizophora racemosa* and *Avicennia germinans* (Adegbehin, 1993). The extraction process involves burning the wood to obtain the white ash, which is then boiled with water in a pot. The ash precipitate is filtered away and the ash solution is sun-dried to obtain the salt. The mangrove roots act as the source of material for salt making and serve as fuel wood for extracting the salt.

Charcoal ash, Malaysia

At Bukit Jugra and Ijok in Selangor, Malaysia, several Chinese restaurants sell poultry baked in smouldering ash of mangrove charcoal. Locally known as beggar's chicken or duck, each poultry is stuffed with herbs and spices, and wrapped in lotus leaves and waxed paper before encasing with clay from red earth. They are then baked for several hours by embedding them in the ash ignited with charcoal. A wheelbarrow is used to cart the freshly baked delicacies to the customers.

Photo: Hung Tuck Chan

Photo: Jessie Lee

Smouldering charcoal ash is used bake the poultry (left) and after a few hours, the delicious beggar's chicken is ready to be served (right).

Fishing stakes, Malaysia

In Malaysia, fishing using gape nets is a popular traditional fishing method in mangrove rivers and estuaries (Chan & Salleh, 1987). There are various types of gape nets but they all employ a similar principle of using incoming and/or receding tides to filter out fish and crustaceans carried by tidal currents. The gear consists of a conical bag net with its mouth stretched open by tidal currents. There are no structural devices to prevent escape of the catch, which is usually retained in the cod end of the net by the force of tidal currents. The net is fastened to mangrove stakes and hauling is done at hourly intervals.

In Sarawak, particularly in the estuaries of Rajang, Belawai, Buntal, Santubong and Sibu rivers, commercial gape nets (*ngian*) are commonly used (Chan & Salleh, 1987). The *ngian* structure consists of a net, which is secured to a framework of 40–50 *nibong* poles. A series of such structures can be constructed alongside each other. The framework of poles also acts as a working platform to facilitate operations. Catch comprises mainly of shrimp. The *ngian* can be operated throughout the year though the favourable months are usually from March to June and from September to December. At Buntal and Santubong rivers, *ngian* fishing is restricted to 2–7 days per month (Rumpet, 1997). Comprising mainly of penaeid shrimp, the average catch per trip is 2.4 kg for Buntal and 8.0 kg for Santubong.

In Penang, the bag net (*pompang*) is commonly used in mangrove estuaries and coastal waters (Lam, 1975; Md Akhir, 1990). The pompang net is about 20 m in length and made of polyethylene material. It is fastened to a pair of *Rhizophora* stakes. When fully opened by the force of tidal currents, the mouth has an opening of 5.5 m and the whole net takes the shape of a cone. Mesh size decreases from 1.5 cm at the wings to 0.5 cm at the cod end. Since this gear depends of tidal currents to operate, fishing is limited to the two periods of high tides of 14–16 days each month. *Acetes* shrimp contribute 35% of the catch. Other gape nets used in


Photos: Suh Cem Pang

A *ngian* showing the bag net and framework of mangrove stakes (left), and lifting the bag net during harvesting (right).

mangrove waterways are the *gombang* and *ambai* (Chan & Salleh, 1987). The *ambai* has a working platform and a V-shaped barrier of mangrove stakes, which guides shrimp and fish carried by the tidal current into the net.

Valakira, Madagascar

In Ambaro Bay, Madagascar, the traditional *valakira* is the best-known small-scale shrimp fisheries (Rabarison, 1989; Razafindrainibe, 2010). The *valakira* is a V-shaped fixed trap comprising a capture chamber, arms and wings. The stakes and lattice used in the wings are different from those of the arms and capture chamber. Traps located at the estuaries have narrower openings of 30º and shorter wings of 10–15 panels. Those placed along the coastline have 60–80º openings and wings of 20–25 panels. Made of bamboo or reeds braided with raphia rope, the panels are held upright by mangrove stakes. The panels need to be repaired regularly or replaced periodically.

With their openings facing seawards, the nets are set up during the new and full moon when the tidal amplitude is at its maximum (Razafindrainibe, 2010). *Valakira* traps are located about 100 m from each other and sometimes laid side by side across the entire river. Its low selectivity results in the capture of juveniles of shrimp and fish. Five shrimp species have been reported with *Penaeus indicus* and *Penaeus monodon* constituting 73% and 11% of the total catch, respectively.


Photo: Frank Lhomme

Photo: Alexis Villain

A *valakira* panel (left) and *Penaeus* shrimp harvested from the traps (right) in Madagascar.

Chapter 3

RECENT WOOD PRODUCTS

Wood Products

Woodchips, East Malaysia

In the 1970s and 1980s, extensive areas of mangrove forests in Sabah and Sarawak of East Malaysia were harvested for woodchips. The woodchips were exported to Japan for the manufacture of rayon and cellophane. An interesting account of Japan's dependence upon woodchips for pulp in the 1970s was reported by Shimokawa (1977). The Japanese pulp industry was the first in the world to utilise mangrove hardwood (considered low grade) for pulp production. With this advancement in technology, the demand for woodchips increased drastically from 23% in 1960 to 74% in 1970. During that period, more than 7,000 chip mills were operating throughout Japan. Some 70 ships, chartered by the Japanese pulp and paper manufacturers, were specially designed for transporting 20,000–50,000 tonnes of woodchips. From 1970–1975, the import of mangrove woodchips from Malaysia amounted to 3.7 million m^3, ranging from 487,000 m^3 in 1970 to 813,000 m^3 in 1974.

In Sabah, the production of mangrove woodchips began in 1971 with the issuance of a license to Syarikat Bakau Sdn. Bhd. in Tawau to log 80,000 hectares of mangrove forests in Cowie Harbour (SFD, 2006). In 1973, Jaya Chip Sdn. Bhd., another company based in Sandakan, started logging 43,300 hectares of the Sandakan-Tambisan mangroves. These two companies exported woodchips of *Rhizophora* and *Bruguiera* to Japan from 1971–1986. In their 15-year operation, some 70,000 hectares of mangroves were harvested, at an annual average rate of 4,600 hectares.

From 1973–1978, the export of mangrove woodchips from Sabah averaged at 213,200 tonnes annually, peaking in 1977 with 267,200 tonnes (SFD, 2006). The woodchips were sold at USD 23 per tonne, generating an annual revenue of USD 260,000 for the state (Tangah, 2005). However, exports dropped drastically from 1979–1986 due to growing international concern of the loss of mangrove ecosystems, especially in Southeast Asia (SFD, 2006). A survey conducted in 1979 by the Sabah Forestry Department in Cowie Bay and Sandakan mangroves showed that some areas logged-over five years ago had little or no regeneration. As the revenue from the export of woodchips was insignificant compared to the damage afflicted upon the fisheries industry and to the 70,000 hectares of mangroves already cleared, the Sabah Government terminated the harvesting of mangrove forests for woodchips in 1986.

Sarawak also had a history of wood chipping, which started in 1968 with Sarawak Woodchip Company given a license to harvest the Rajang delta mangroves based on a 25-year rotation and annual coupe of 607 hectares (Chan et al., 1993). With an annual felling rate of double the annual coupe, harvesting was soon halted due to the depletion of timber.

> To make rayon or artificial silk, woodchips are treated with carbon disulphide, which converts the insoluble cellulose to soluble cellulose or xanthate. The latter is dissolved in sodium hydroxide to form a thick viscous solution (viscose). The viscose is then allowed to ripen or age to recover the cellulose. Rayon fibres are produced by forcing the cellulose through spinnerettes with many tiny holes into a bath containing dilute sulphuric acid, which neutralises sodium hydroxide and decomposes the xanthate. The extruded yarn is then washed, bleached and dried. To produce cellophane, the regenerated cellulose is extruded through a slit machine, yielding thin films of cellophane, which is neutralised, washed and dried. [Sources: Jenkins, 1997; Manivasakam, 2011]

Photo: Hung Tuck Chan

A mangrove woodchip mill in Sarawak.

Overall, the socio-economic returns from woodchip production were poor and the degradation of the mangrove was extensive (Ong, 1982). Harvesting of mangroves for woodchips in Sabah and Sarawak could have been managed on a sustained yield basis with more care and less greed (Ong, 1995). The harvesting and export of mangrove woodchips have become a historic event in Malaysian forestry with ample lessons learnt.

Pulp and paper, Bangladesh

The Khulna Newsprint Mill, the first in Bangladesh, started operation in 1959 to meet the country's needs for newsprint (FAO, 1973; Alam, 2006). Located along the Bhairab river at Khalishpur in Khulna, the mill used *Excoecaria agallocha* (*gewa*), a common mangrove species in the Sundarbans, as raw material.

Gewa trees harvested for pulp and paper were crooked, and the wood was hard but of relatively low density (FAO, 1973). The white sap from the wood caused skin irritation and eye discomfort. The cut wood darkened when exposed and had to be submerged in rivers before towing to the mill. Some 8,000 hectares of *gewa* forests were logged annually to supply the mill. During the monsoon season, the timber inventory had to be built up as towing and logging operations were no longer possible. The mill had an installed capacity of producing 45,000 tonnes per year of newsprint (Gupta, 1999). It was reportedly operating at only about 20% capacity. Following the declaration of the Sundarbans as a world heritage site, the Forest Department imposed a ban on the felling of *gewa* trees and the mill was forced to shut down in 2001 due to inadequate wood supply (Alam, 2006).

Excoecaria agallocha (Euphorbiaceae) is a medium-sized tree, 6–12 m tall with low branches. The bark is grey, smooth with longitudinal rows of corky lenticels. Leaves are simple, alternate, shiny and leathery, with pointed tips and bluntly toothed margins. They are 6–10 cm long, pinkish in colour, turning green and then bright red before aborting. Male and female flowers are present on separate trees (dioecious). Flowers are tiny, fragrant with yellowish-green calyx and greenish-white petals. Fruits are small, round and clustered, each with three seeds. The species produces a milky sap, which can cause pain and blistering when comes in contact with the skin, and can cause temporary blindness when gets into the eyes. [Source: Selvam 2007]

Photo: Hung Tuck Chan　　Photo: Wood Explorer

Leaves (left) and wood (right) of *Excoecaria agallocha.*

Pulp and paper manufacturing processes involve chipping, pulping, bleaching and paper production. After wood chipping, pulp is produced by mechanical, thermo-mechanical, chemi-mechanical and chemical methods. Mechanical pulping separates fibres by disc-abrasion and billeting. Thermo-mechanical pulps, which are used for making newsprint, are manufactured by the application of heat, in addition to mechanical operations. Chemi-mechanical processes involve mechanical abrasion and the use of chemicals. For most paper, the pulp has to be bleached with chlorine dioxide, washed with water and dried. Paper is made from bleached pulp by placing fibres and fillers in fluid suspension onto a forming device. Water from the pulp is removed by pressing and drying. Chemical additives are added to impart specific properties to the paper and pigments may be added for colour. [Source: WBG, 1998]

Wood vinegar, Malaysia

In recent years, charcoal operators at Kuala Sepetang and Sungai Kerang in Matang, Malaysia, have started to produce wood vinegar as a by-product of charcoal making (Azahar & Nik Mohd Shah, 2003). The by-product collected as raw distillate is pyroligneous acid. Consisting of a network of long stainless steel tubes and funnels as condensers, the equipment is attached to one of the smoke vents of the charcoal kiln. Smoke from the vent is condensed and collected. Operators in Sungai Kerang have improvised the distillation process using plastic tubes and drums, which are cheaper to construct and easier to assemble.

Photos: Hung Tuck Chan

Smoke collected at a vent moves up a steel pipe (left) and on condensation, wood vinegar flows back into a drum (right).

In Matang, mangrove wood vinegar is collected at Stage II of the firing schedule when the entrance of the kiln is partially sealed to prevent complete combustion (Loo, 2008). During this stage of charcoal production (12–14 days in duration), the temperature inside the kiln reaches 250ºC, and smoke emerging from the vents of the kiln is about 50–70ºC. The smoke, collected using a stainless steel cone, is channelled through a steel pipe where it condenses and the wood vinegar flows back into a drum. Freshly collected wood vinegar has a temperature of 36–38ºC and a smoky odour. The condensate when fractionated yields 5.5% acetic acid, 3.4% methanol and 6.5% wood tar. Due to its high amount of volatile acids (8–10%), wood vinegar is acidic (pH 2–3) and mildly corrosive.

Before distillation, wood vinegar is almost black in colour, resembling coffee (Chan et al., 2012a, 2012b). After distillation, it becomes a golden brown liquid, resembling tea. Wood vinegar has been traditionally used as steriliser, deodoriser, fertiliser, and antimicrobial and growth-promoting agent (Loo, 2008). It has a wide range of industrial, agricultural, medicinal and home applications. In Thailand, wood vinegar is used to treat skin infections and dandruff (Rakmai, 2009).

Extracts of wood vinegar from Matang have been studied for its phenolic content and antioxidant properties, with the isolation of three antioxidative compounds (Loo et al., 2007, 2008). Antioxidant properties of the Matang wood vinegar, in its original liquid form, were stronger than or comparable with those of black tea (*Camellia sinensis*) at 24 mg/ml (Chan et al., 2012a). Potent and broad-spectrum antibacterial activity of the mangrove wood vinegar has also been reported (Chan et al., 2012b). Using the agar-well diffusion technique, both the distilled and non-distilled wood vinegar at 50% concentration inhibited all six Gram-positive and Gram-negative bacteria tested (Table 3.1).

Photos: Hung Tuck Chan

Wood vinegar is almost black before distillation and golden brown after distillation (left), and bottles of distilled wood vinegar produced by a factory in Matang (right).

Table 3.1 Diameter of inhibitory zone (DIZ) and minimum inhibition concentration (MIC) of distilled and non-distilled wood vinegar against Gram-positive and Gram-negative bacteria (Chan et al. 2012b)

Wood vinegar	Gram-positive bacteria					
	Bacillus cereus		*Micrococcus luteus*		*Staphylococcus aureus*	
	DIZ (mm)	MIC (%)	DIZ (mm)	MIC (%)	DIZ (mm)	MIC (%)
Distilled	15 ± 1	6.25	27 ± 2	12.5	20 ± 1	12.5
Non-distilled	15 ± 1	6.25	28 ± 2	12.5	21 ± 1	12.5

Wood vinegar	Gram-negative bacteria					
	Escherichia coli		*Pseudomonas aeruginosa*		*Salmonella typhi*	
	DIZ (mm)	MIC (%)	DIZ (mm)	MIC (%)	DIZ (mm)	MIC (%)
Distilled	10 ± 2	25.0	15 ± 0	12.5	9 ± 2	25.0
Non-distilled	13 ± 2	25.0	17 ± 1	12.5	13 ± 1	25.0

White charcoal, Southeast Asia

In Southeast Asia, white charcoal is produced from *Rhizophora* wood by carbonising at a moderately low temperature (Kuniko, 2001; Amir, 2005). Towards the end of the process, the charcoal is made red hot by raising the kiln temperature to 1,000ºC. When making white charcoal, the deep red charcoal is removed from the kiln, and quickly smothered and cooled with a mixture of powdered sand, earth and ash. This gives a whitish colour to the outer surface of the charcoal. The rapid rise in temperature, followed by quick cooling, result in a smooth hardened outer surface. When struck, there is a clear metallic sound. White charcoal may take some time to ignite, but its thermal conductivity is superior to that of black charcoal and its flame lasts longer. White charcoal is smokeless and odourless, has a long-lasting burn, which is extremely hot and smokeless. When ignited, it produces a subtle natural aroma and barbecued food does not have a smoky flavour. It can be extinguished and re-used. The current price of black charcoal produced in Malaysia is USD 200 per tonne. White charcoal fetches up to USD 14,000 per tonne.

Photo: Hung Tuck Chan

White charcoal produced from mangrove wood.

A product quality analysis conducted by Mesjaya Enterprise & GH White Charcoal, a charcoal company based in Indonesia and Malaysia (BTCL, 2010), reported the following specifications for white and black charcoal (Table 3.2).

Table 3.2 Specifications of white and black charcoal (BTCL, 2010)

Specification	White charcoal	Black charcoal
Ignited temperature (ºC)	1100–1200	400–500
Fixed carbon content (%)	94.6	75.1
Volatile matter content (%)	4.1	21.9
Ash content (%)	1.3	3.0
Moisture content (%)	4.8	8.7
Burning duration (hour)	4–6	1–2

Charcoal Products

Briquettes, Southeast Asia

Charcoal production in Southeast Asia generates a large quantity of chips and fines at the kilns (Chunwarin et al., 1982; Amir, 2005). These materials can be made into useful products such as briquettes by crushing them, mixing with yellow clay and sawdust in the ratio of 8:1:1, and pressing them in moulds. Sometimes, a binder such as starch is used. After drying, they become charcoal briquettes with similar or better quality than charcoal itself. Charcoal briquettes, which offer the advantage of slow smokeless burning, are popularly used for barbecuing in restaurants and hotels. Black in colour, the briquettes are hexagonal in shape of 40 cm length and 5.4–5.5 cm diameter. They have a round inner hole of 2.0–2.2 cm diameter.

Photos: Hung Tuck Chan

Mangrove charcoal chips and fines (left), and briquettes produced (right).

Miscellaneous products, Malaysia

In Malaysia, mangrove charcoal chips and fines are also processed into a variety of useful products, which are exported to Japan. They include fire igniters, soil conditioners, fertilisers, water filters, air purifiers and deodorisers.

Photos: Hung Tuck Chan

Useful products from mangrove charcoal chips and fines.

Chapter 4

TRADITIONAL NON-WOOD PRODUCTS

Products from *Nypa* Leaves

Thatches, Malaysia

In Peninsular Malaysia, the weaving of thatches (*atap*) from leaves of *Nypa fruticans* (*nipa*) continues to be an important traditional cottage industry among the coastal Malay villagers (Chan, 1986; Chan & Salleh, 1987). There is still a strong demand for thatches as roofing and walling material for poultry and pig farms, and charcoal kilns. In *atap* making, there is a clear division of labour between the genders. The men would collect the leaves from the forest while the women would weave them into thatches.

Nypa fruticans (Palmae) is a monotypic mangrove palm that grows up to 10 m tall and forms gregariously stands. Fronds are slightly curved with a stout stalk that is strongly flanged at the base. Each frond has 100–120 leaves with a shiny green upper surface, pale lower surface and midrib marked by brown scales. The species is monoecious with female flowers forming a spherical head. The bright yellow male flowers are catkins, located below the female head of flowers. The fruiting body is a spherical aggregate of individual brown fruits, which are obovate, angular and fibrous. Each fruit contains a white, egg-shaped seed with edible endosperm. The species occurs along the banks of the upper reaches of tidal rivers where there is a regular supply of fresh water. [Sources: Giesen et al., 2007; SFD, 2010]

Photo: Hung Tuck Chan

A gregarious riverine stand of *Nypa fruticans*.

Photo: Hung Tuck Chan

Photo: Koichi Tsuruda

Photo: Vien Ngoc Nam

Photo: Hung Tuck Chan

Weaving *Nypa* thatches is done by the womenfolk (top left), woven thatches are placed in the sun to dry (top right), and thatches for housing charcoal kilns (bottom left) and for ornamental use (bottom right).

Nipa leaves are harvested throughout the year, the amount harvested depends on market demand (Fong, 1992). *Nipa* leaves are gathered from mature fronds of about 12 months of age by cutting about 0.6–1.0 m from the ground level using a knife. Only the middle sections with the longest leaves are used as weaving material. Severed leaves are tied into bundles (Chan, 1986; Chan & Salleh, 1987). It is customary among the collectors to retain the first pair of young fronds for a given plant to ensure its recovery. Leaves are usually harvested once every six months.

In the weaving of thatches, leaf stalks of *nipa* or coconut are cut into 1.5 m length, spliced into 5–6 divisions and are used as the rib (Chan, 1986; Chan & Salleh, 1987). Two or three leaves are then folded approximately mid-way over the rib and stitched in place using a strip of peel removed from the leaf stalks. Weaving is usually done beneath stilt houses or under *atap* sheds by the womenfolk. Taking 3–4 minutes to weave a single thatch, a woman can produce 50–60 pieces a day. Occasionally, women are employed to do the weaving and are paid based on the number of thatches woven. It is preferred that freshly collected leaves be used for they are more pliable and hence easier to fold and weave. Woven thatches are then arranged in rows to be dried in the sun for about a week. After drying, they are tied into stacks of 25 pieces and sold to consumers who are largely operators of charcoal kilns, poultry farms and piggeries. An *atap* maker can produce up to 2,000 pieces of thatches per month. The durability of *nipa* thatches depends largely on the angle of pitch and degree of overlapping. A high-pitched roof with closely stacked thatches can last up to five years without replacement or major repairs. Thatches from *nipa* leaves last much longer than those made from coconut leaves (Kabir & Hossain, 2007).

In Sabah and Sarawak, the collection of *nipa* leaves for weaving thatches is essentially similar to that in Peninsular Malaysia (Chan & Salleh, 1987). Local villagers also make thatches for room partitioning and window screening. These thatches are three-ply and woven with rattan peels to form a continuous sheet measuring 2.0 x 2.5 m. Young leaves are normally used for the outermost layer. A series of additional stitching at 30 cm intervals along the entire length afford firmness to the sheets.

Thatches, Bangladesh

Nypa fruticans (*golpatta*) is one of the most valuable mangrove plants of the Sundarbans in Bangladesh (Basit, 1995; Kabir & Hossain, 2007). It is common along the upstream banks of tidal channels and rivers, and in swampy localities in the interior of mangrove forests. The extent of *golpatta* forest has been estimated at 6,000 km^2. The leaves are principally used as thatching material, but they can be made into a variety of woven products. Sap from the cut stalk of fruit bunches can be processed into sugar, alcohol and vinegar. Ripe fruits are edible. Annually, some 19,200 people would harvest fronds from the Sundarbans and market them in nearby villages at USD 12 per tonne. The season for harvesting *golpatta* fronds is from October to March. Traditionally, the thatches are used as roofing and walling material. The production of thatches is very common in the districts of Khulna, Bagerhat and Sarkhira (Khan, 1994). From 1975–1987, the annual production of fronds in the Sundarbans ranged from 61,400–83,700 tonnes.

Cigarette wrappers, Malaysia

The manufacture of cigarette wrappers (*daun rokok*) from young leaves of *Nypa fruticans* (*nipa*) remained a flourishing industry in Kedah and Perak, Peninsular Malaysia (Chan, 1986; Chan & Salleh, 1987). Two groups of people are involved in the industry. The coastal Malay villagers are involved in collecting, preparing and drying the leaves. The Chinese middlemen are involved in bleaching the leaves followed by cutting, packing and distributing the processed product.

Young unfolded *nipa* fronds, more than four months of age and have attained lengths of 5–6 m, are cut by the local villagers (Chan, 1986; Chan & Salleh, 1987; Fong, 1992). One man can usually cut about 100 fronds in a day. The fronds are pried open and the leaves severed from the stalks using a knife, each cut removing a pair of attachment. About 60–80 leaves can be obtained from each frond, representing about 300 g of dried material. Young leaves at the tip of each frond are usually discarded in view of their small size and tenderness. The leaves are then tied into bundles.

The next process involves stripping the cuticle from leaves and this is usually done by the womenfolk (Chan, 1986; Chan & Salleh, 1987). It requires special skills and many hours of patient work. A leaf is taken and one of the blades is stripped from the mid-rib with a swift tearing motion. Beginning from the basal edge of the blade, the cuticle is separated sufficiently using the teeth to allow the introduction of a finger, which is quickly forced against the point of attachment until the blade is completely skinned. The remaining blade with the adhering mid-rib is treated similarly removing the cuticle and mid-rib concurrently. To protect abrasion

Photos: Hung Tuck Chan

In Malaysia, stripping the cuticle from young leaves of *Nypa* is done by the womenfolk (top left), grading of bleached leaf blades (right), and cigarette wrappers are sold in small bundles and packets (bottom left).

of their fingers, women often wear gloves. The skinned blades are then sun-dried for a day. During drying, the leaf blades curl slightly emitting a distinct crackling sound. The dried materials are then tied into bundles and sold to the middlemen. The monthly production per household varies from 240–360 kg.

The dried materials are transported to Teluk Intan in Perak, the centre for the *daun rokok* industry (Chan, 1986; Chan & Salleh, 1987). Here, the bundles of blades are bleached with sulphur dioxide in specially constructed wooden chambers of burning sulphur. The process requires 2–3 hours per batch and is essential in that the blades will then become more pliable and easier to roll during tobacco smoking. The treated materials are graded, cut into lengths suitable for smoking and sold in small bundles or packets. Consumers of *daun rokok* are mainly paddy farmers who prefer smoking *nipa*-wrapped tobacco to ordinary cigarettes as they are cheaper and can withstand some amount of wetting.

Nipa cigarettes, Indonesia

In West Aceh, Indonesia, young leaves of *Nypa fruticans* (*nipa*) are harvested for making cigarette wrappers (Joshi et al., 2006). It is a major secondary occupation for many households. The harvesting of *nipa* leaves is done every three months over a period of 2–3 days. This gives time for the leaves to re-grow. However, those who own *nipa* plantations harvest the leaves monthly. Nearly 50% of the villagers in Samatiga work in plantations producing tobacco wrappers, roof thatches and woven products. A women's group in the village of Cot Darat also produces hand-rolled *nipa* cigarettes. The group has produced about 75,000 sticks of cigarettes, which are sold locally to the retail shops. From one hectare of *nipa* forest, the small-scale industry could generate an income of USD 220. This is a substantial income for the locals, who earn less than USD 3 per day from fishing or farming.

Products from *Nypa* Sap

Sugar and wine, Thailand

In Pak Phanang District, Nakhon Si Thammarat Province in southern Thailand, natural forests of *Nypa fruticans* cover an area of 3,200 hectares (Bamroongrugsa et al., 2004). About 90% of the households in the district derive their livelihood from tapping *Nypa* sap for production of beverage and sugar (Thu Ha, 2004). It has been estimated that one hectare of *Nypa* forest yields 2,400–3,000 litres of sap or 1,000 kg of sugar per month. Tapping is done for eight months in a year. Each household can earn up to USD 1,350 per year from selling *Nypa* beverage and sugar.

Sap is generally collected from the fruit stalk after the almost full-grown fruiting head has been cut (Bamroongrugsa et al., 2004; Thu Ha, 2004). Preparation of the stalk is essential to stimulate sap flow. It involves beating the stalk 40–50 times daily for three days. After an interval of 10 days, the beating process is repeated once or twice. Tapping begins by cutting off a thin slice of the stalk tip. When oozing commences, the sap is collected in bamboo tubes. It is estimated that a stalk can produce about 0.7 litres of sap daily. A skilled worker is able to tap as many as 100 stalks per day.

Photo: Phan Nguyen Hong

Photos: Le Thi Thu Ha

In southern Thailand, *Nypa* sap is tapped by beating the fruit stalk with a pair of wooden mallets (left), bamboo tubes are used as containers for the sap (top right), and shavings of *Rhizophora* wood are used as additive (bottom right).

When freshly tapped, the sap is sweet. After several hours, it becomes alcoholic (*toddy*). Shavings of *Rhizophora apiculata* wood are used as a preservative to control the acidity and to slow down the fermentation process (Thu Ha, 2004; CORIN-Asia, 2009a). Currently, there are three factories in Nakhon Si Thammarat producing *Nypa* wine. The process involves adding yeast to the *toddy*, storage in plastic drums for 2–3 days and distillation before bottling. The factories produce more than 400 bottles of *Nypa* wine per day.

In the production of *Nypa* sugar, the sap is immediately transported in plastic containers to the depot for processing (Thu Ha, 2004). At the depot, the sap is sieved and boiled under medium heat in large woks placed over earthen stoves for 1–2 hours with continuous stirring till a thick golden-brown viscous syrup is formed. The sugar is allowed to cool with stirring continuing for another 25–30 minutes before it is sold in tin containers. From 100 litres of sap, the yield of sugar is 20 kg (Bamroongrugsa et al., 2004). Containing 4–17% of sucrose, *Nypa* sugar is used primarily as a confection for cakes and desserts, and as an elegant sweetener for coffee and tea (Thu Ha, 2004; CORIN-Asia, 2009a).

Photos: Le Thi Thu Ha

In southern Thailand, freshly collected sap is boiled in a wok under medium heat (left) with continuous stirring (middle) and on cooling, the sugar is sold in tin containers (right).

Vinegar, Philippines

In the Philippines, *Nypa* vinegar is commercially produced in Paombong, a town in Bulacan District (Sanchez, 2008). Cloudy white in colour, the vinegar has a peculiar aroma. Compared to coconut vinegar, *Nypa* vinegar is less sour and has the tendency to darken as it ages (Lim-Castillo, 2006). Old Filipino folks claim that if *Nypa* vinegar does not darken, it is not pure.

There are 47 *Nypa* vinegar enterprises in Paombong with some having been in the business for more than 20 years (Munoz, 2010). Most of these enterprises are located near *Nypa* forests to facilitate sap collection. The sap is poured into huge earthen jars. Upon completion of fermentation, which can take up to a month, the vinegar is checked for its acidity (Lim-Castillo, 2006). When the content of acetic acid reaches 4%, the vinegar can be bottled for sale. During the peak months, small enterprises can sell up to USD 400 worth of vinegar with a net monthly income of USD 240 (Munoz, 2010). Larger enterprises can sell up to USD 10,000 worth of vinegar with a net monthly income of USD 5,000.

Nira, Southeast Asia

Fresh tapped sap of *Nypa fruticans* (*nira*) is a popular drink that is sold in the coastal areas of Southeast Asia. The fruit bunch is shaken and the stalk is bent over to allow the *nira* to ooze out when cut. Tapping involves slicing off the cut end to sap out-flow. The milky white and sweet *nira* has to be consumed the day it is tapped, for it ferments spontaneously. After a day or two, it becomes an alcoholic drink with 6–12% alcohol content (Päivöke, 1996; Sanchez, 2008). Fresh *nira* has a sucrose content of 15–16% and pH of 7.5.

Photo: Le Thi Thu Ha

Photo: Dyldude

Photo: Mami Kainuma

Bottled *Nypa* beverages sold as wine in southern Thailand (left), as vinegar in the Philippines (middle), and as fresh *nira* in Malaysia (right).

Beverages

Kirala juice, Sri Lanka

In the southern and southwestern coast of Sri Lanka, local communities such as those at Kalametiya and Kahandamodara consume the fruit juice of *Sonneratia caseolaris* (*kirala*) (Jayatissa et al., 2006). Fruits are collected over a period of three months per year and each tree produces about 350 fruits annually (Batagoda, 2003). The fruits are sold as USD 4 per thousand, but infestation by insects can affect the quality and yield of fruits.

Sonneratia caseolaris (Sonneratiaceae) is a medium-sized mangrove tree growing up to 15–20 m tall. Leaves are elliptic with curved tips. Flowers have numerous white stamens that are bright pink at the base and produce much nectar. The edible fruits are round and flattened, green when young, with horizontally extended calyx and persistent long style. Found along the upper reaches of rivers with greater freshwater influence and associated with fireflies, the species can be distinguished by its spreading crowns, horizontal branches and drooping twigs. [Sources: Selvam, 2007; Giesen et al., 2007]

When preparing the juice, mature fruits are washed and their calyx removed (Jayatissa et al., 2006; Abeywickrama & Jayasooriya, 2010). The fruits are then squashed by hand and mixed well with water to get a homogenous juice, which is filtered with a mesh to remove the seeds and skin. Some sugar is added before the juice is served. When freshly prepared, the drink is refreshing with a fruity flavour. When kept for 24 hours, the juice becomes unpalatable with a strong astringent taste due to fermentation and enzymatic browning. Use of blenders is not recommended. The fruits contain a large number of small seeds, which are damaged during blending and this accelerates the browning effect.

Kirala fruit juice is rich in dietary fiber, calcium and phosphorus (Jayatissa et al., 2006). Fruits have potent ability to scavenge free radicals and to inhibit lipid peroxidation (Bunyapraphatsara et al., 2002). Out of 20 mangrove plant species screened, fruits of *kirala* ranked second in radical scavenging and first in lipid peroxidation inhibition. Oxidative damage due to free radicals and lipid peroxidation are known to cause cardiovascular disorders. Thus the fruit juice of *kirala* can be consumed as a natural health drink with cardiovascular protective properties.

An improved method of preparing the fruit juice by freeze-thawing has been developed (Jayatissa et al., 2006). Partially ripened fruits are washed and kept at room temperature for 12 hours to allow further ripening. The fruits are then frozen after removing their calyx. The frozen fruits are thawed and their skin removed. Water (1:1 w/w) is added and then stirred using a plastic stirrer to obtain a cream. More water is added and seeds are removed by filtering. The whole procedure is completed within a short period to minimise enzymatic browning. After adding sugar and preservatives, the fruit mixture can be used to prepare concentrated fruit cordial or ice cream with a shelf-life of more than six months. This procedure has now been patented in Sri Lanka.

Photos: Suminda Prabath

In Sri Lanka, mature fruits of *Sonneratia caseolaris* (*kirala*) are collected (top left), after removing the calyx, the fruits are hand squashed and sieved to obtain the fruit juice (top right), after adding some water and sugar, the drink is ready for serving (bottom right), and taking the first sip of the juice (bottom left).

Pedada syrup, Indonesia

In Indonesia, mature fruits of *Sonneratia caseolaris* (*pedada*) are harvested to make syrup (Priyono et al., 2010). The process involves peeling and cutting the fruits into pieces before blending and boiling with water. The fruit juice is then filtered into sugar solution with some citric acid added, followed by boiling in low heat. After cooling, the brown *pedada* syrup can be bottled for sale in the market.

Photo: Made Suartana

Brown *pedada* syrup bottled for the market in Indonesia.

Sonneratia juice, Maldives

In the Maldives, fruits of *Sonneratia caseolaris* sold in the market are eaten raw or drank as fruit juice (Thupalli, 2005; Selvam, 2007). The species is cultivated in home gardens at Kulhudhuffushi by the local people for its fruits and fruit juice. The latter is consumed as a traditional drink.

Edible Plant Parts

Nypa fruticans, Southeast Asia

Young seeds of *Nypa fruticans* are edible. The white and soft endosperm is eaten fresh as a refreshing dessert or snack (Fong, 1992; Johnson, 1992; Päivöke, 1996). Known as *atap chi* in Malaysia, they are served as one of the ingredients in local ice confections (Hamilton & Murphy, 1988). In Tra Vinh Province, Vietnam, young *Nypa* fruits are collected by the local people (Thu Ha, 2004). The seeds are spliced open to obtain the white and soft endosperm, which is sold as a delicacy in the market.

Rhizophora apiculata, Malaysia

In Malaysia, the Bajau womenfolk at Kampung Penimbawan, Tuaran, Sabah, produce a condiment from flower buds of *Rhizophora apiculata* (SWCS, 2011). Mature buds collected are removed of their calyx and pounded in a mortar, and mixed with shrimp paste (*belacan*), salt, chilli, and tamarind or lime juice. The hot and spicy paste is eaten together with main dishes.

Bruguiera, Pacific Islands

Propagules of *Bruguiera gymnorhiza* are eaten cooked, after scraping or grating, washing, and drying (to remove tannins) and sometimes mixed with coconut in Melanesia and Nauru (Thaman, 1992; Clarke & Thaman, 1993). They are sold as a vegetable in the market of Honiara in Solomon Islands.

Photos: Shigeyuki Baba

Young *Nypa* fruits are collected by the local people of Tra Vinh Province in Vietnam (left), spliced to obtain the white and soft endosperm (top right), and sold as a delicacy in the market (bottom right).

Photos: Ka Han Lee

In Sabah, Malaysia, mature buds of *Rhizophora apiculata* are collected (top left) and pounded in a mortar (top right) with shrimp paste (belacan), salt, chilli and tamarind or lime juice added for taste (bottom left), and the hot and spicy condiment is ready for consumption (bottom right).

Photo: Shoko Yamagami

Photo: Hung Tuck Chan

Propagules of *Bruguiera cylindrica* (left) and fruit of *Sonneratia caseolaris* (right).

Bruguiera and Sonneratia, Maldives

In the Maldives, propagules of *Bruguiera cylindrica*, *Bruguiera gymnorhiza* and *Bruguiera sexangula* are consumed after removing the skin and boiling them several times, first with ash to remove their bitterness and then with salt for taste (Selvam, 2007). Fruits of *Sonneratia caseolaris* are sold in the market. Taste like cheese, they are eaten raw and relished by the local people including children.

Sesuvium portulacastrum, Asia Pacific

Sesuvium portulacastrum (Aizoaceae) is a spreading, creeping and succulent perennial herb, commonly growing in dense patches at the landward of mangroves (Giesen et al., 2007). In the Pacific, the herb is eaten raw or boiled (Thaman, 1992). In Kiribati, the plant is used as pig feed.

In the Bhitarkanika wildlife sanctuary, Orissa, India, the local people consume the stems and leaves of *Sesuvium portulacastrum* after boiling to remove excess salt (Pattanaik et al., 2008).

Photos: Shigeyuki Baba

Plants (left) and flower (right) of *Sesuvium portulacastrum*, and its fusion into Okinawan cuisines of *tempura* (left) and *tofu-champuru* (right).

In Okinawa, Japan, recipes for cooking local dishes using *Sesuvium portulacastrum* have been developed. The dishes represent a fusion of the coastal element into the Okinawan culinary tradition. Before cooking, plants are washed, soaked in vinegar for an hour before blanching in hot water for a few minutes, and draining the water to remove the astringent and bitter taste.

Acrostichum aureum, Sri Lanka

In Kiralakale, Sri Lanka, the young fronds or fiddleheads of *Acrostichum aureum* (*karan koku*) are sold in the market and eaten as a vegetable (Batagoda, 2003). A clump produces six edible shoots over a period of six month per year which are sold at USD 40 per tonne. The fern is also eaten in Indonesia, raw but more often, steamed or blanched (MAP, 2006).

> *Acrostichum aureum* (Pteridaceae) is a mangrove fern that grows to 3–4 m in height. Stems of fronds are stout, erect and covered with scales. Tips of fertile leaves are rusty-brown during spore release. Spores are large and tetrahedral in shape. Tips of sterile leaves are blunt with a short tip. Leaf venation is net-like. The species can be distinguished from *Acrostichum speciosum* by being taller, with young fronds being reddish and mature leaves with blunt tips. In open and inland areas that are seldom inundated, the fern grows in tall dense thickets. [Source: Giesen et al., 2007]

Photo: Hung Tuck Chan

Edible young fronds of *Acrostichum aureum*.

Pandanus tectorius, Pacific Islands

Throughout the Pacific, the fleshy keys of *Pandanus tectorius* fruits are consumed fresh or made into various preserved foods (SPC, 2006; Thomson et al., 2006). The fruits are green when young, turning to yellow and then orange or orange-red when mature. The bunches have a characteristic sweet fragrance when ripe. In Micronesia, adults consume more than 20 fresh keys daily during the fruiting season. Chewing fresh keys is usually done between meals, which is a pleasurable and considered a highly social activity.

Not all fruits of *Pandanus tectorius* are edible with some varieties having oxalate crystals, which cause mouth irritation (Englberger et al., 2003). The fruits of different varieties are distinct in size, shape, colour, flavour and juiciness. The fruits are rich in vitamin C and carotenoids, including β-carotene (Englberger et al., 2003; Dignan et al., 2004). Varieties with soft keys can be eaten raw while those with fibrous keys are processed into paste or flour before consumption (SPC, 2006).

Photos: Shigeyuki Baba

Young (left), maturing (middle) and mature (right) fruits of *Pandanus tectorius*.

Arrowroot, Pacific Islands

Tacca leontopetaloides (Taccaceae) or arrowroot is naturally distributed from West Africa through Southeast Asia to northern Australia. The species was introduced to the Pacific by early human settlers (Spennemann, 1994; NTBG, 2012). In the Pacific, the species is found in the Marshall Islands, Kiribati and Micronesia. It is a coastal perennial shrub with large and deeply lobed leaves. The leaf upper surface has depressed veins and the under surface is shiny with bold yellow veins. Flowers are borne on tall stalks in greenish-purple clusters, with long-trailing bracts. Tubers are hard and potato-like, with a brown exterior and white interior.

Arrowroot tubers contain 10–25% of starch (Spennemann, 1992). Its fine crystal structure makes the starch easily digestible. Flour prepared from the tubers is used to make a variety of pudding (NTBG, 2012). The tubers are first grated and then soaked in fresh water. The settled starch is rinsed repeatedly to remove the bitterness and then dried.

Photos: Shigeyuki Baba

Pulling out an arrowroot plant (left) to show the potato-like tuber with white starchy interior (right) in Kiribati.

Bark for Dyeing

Cotton fabric, Japan

Dyeing of cotton fabric using the bark of mangrove trees was an important traditional industry on the Ryukyus Islands of Okinawa, Ishigaki and Iriomote in the southernmost part of Japan (Baba, 2004). This natural dye technique, known as *kusaki-zome*, uses the bark of *Rhizophora stylosa* (*yaeyama hirugi*). The dye colour of the outer bark is brownish and that of the inner bark is reddish. The bark of *Bruguiera gymnorhiza* and *Heritiera littoralis* is sometimes used, yielding brownish and reddish-purple dyes, respectively.

Rhizophora stylosa (Rhizophoraceae) is a mangrove tree that grows up to 3–5 m in height. Gnarled in form, trees produce multiple stems, extensive reddish brown stilt roots, and aerial roots from branches. The bark is reddish-brown with no fissures. Leaf blade is broadly elliptic with the apex ending in an extended tip (4–5 mm). At the under surface, the midrib is pale green and many prominent black dots are discernable. Leaf stalk is 2.5–3.5 cm long. Inflorescences are branched 2–4 times with 4–8 buds borne on an elongated peduncle. Flowers are inverted with hairy white petals and a characteristically elongated style (4–5 mm). Fruits are dark brown when ripe, ovate and 2 cm long. Propagules have a yellow collar that is slightly swollen. Hypocotyls (30–32 cm) are cylindrical, warty with a pointed tip. The species is confined to the flats of rocky and sandy shores. [Sources: Chan & Baba, 2009; Ng & Chan, 2012]

Photos: Shigeyuki Baba

Flowers (left) and bark (right) of *Rhizophora stylosa* in Iriomote, Japan.

In Iriomote, the process of *kusaki-zome* involves collection of *yaeyama hirugi* branches and bark removal by beating with a stick. Pieces of the bark are collected and placed into a dye pot of water to boil for 30–60 minutes. When sufficient colour is produced, the cotton fabric is immersed into the dye extract (cutch) and boiled for 1–2 hours. Colouring patterns can be created by knotting, tying and clamping with strings, elastic bands, sticks and blocks.

The dyed fabric is then rinsed in water and placed into lye to fix the colour. To produce a deeper colour, the fabric is again dyed and fixed in lye. The alkaline lye is a dye mordant produced from wood ash. After untying, the dyed fabric is then rinsed in seawater to enhance and stabilise the colours before drying in the sun. To produce other colours, different dyes can be used. To generate black colour, mud from paddy fields can be used. To produce indigo blue and yellow colour, *Polygonum tinctorium* leaves and *Garcinia subelliptica* bark are used, respectively.

The technique of dyeing fabric using *yaeyama hirugi* bark has been developed by Ms. Akiko Ishigaki, a dyeing and weaving specialist in Iriomote. She weaves and dyes her own yarn and fabric. She keeps her traditional art alive through her own work and the training she provides to younger people (McCarty & McQuaid, 1998). According to her, '*One of the most beautiful aspects of the dyeing process is seeing the fabric when it is rinsed in the sea. This act not only stabilises the dye but reinforces its poetic connection between the land and sea, from which it is created*.'

Photos: Shoko Yamagami

Removing the *yaeyama hirugi* bark (top left), boiling the bark in pots of water to extract the dye (top right), knotting the cotton cloth for dyeing (bottom left), and creating colour patterns using strings, elastic bands, sticks and blocks (bottom right).

Photo: Mio Kezuka Photo: Shoko Yamagami Photo: Asuka Miyazato

Immersing the fabric into boiling dye solution (left), fixing the colour of the dyed fabric in lye (middle), and untying and washing the dyed fabric in seawater to remove remaining dye (right).

Photo: Shoko Yamagami

Photo: Shoko Yamagami

Photo: Shigeyuki Baba

Photos: Shoko Yamagami

Dyed fabric is rinsed in seawater (top), dried in the sun (middle row), and dyed yarn being dried (bottom left) and woven (bottom right).

In the past, villagers of Iriomote harvested *yaeyama hirugi* bark from the forest by beating the trunk of trees with a wooden mallet and stripping the bark (Nakama, 2004). Harvesting was selective with only the bark of large trees removed. A villager could collect up to 60 kg of bark per day. The bark was then sent to the dye factories in Iriomote or Ishigaki for production of cutch (*kacchi*). The process involved adding pieces of bark into pots of water to boil. When concentrated, the essence was poured into moulds with lime added to facilitate the drying process. *Kacchi* was sold throughout the Ryukyus for preserving nets and sails, and as patty for sealing water leaks.

Tapa cloth, Pacific Islands

The bark of mangrove trees is important as dye for *tapa* cloth in the Pacific Islands (Green, 1989; Murofushi & Hori, 1997; Day, 2000; Rohorua & Lim, 2006). The rich brown colour of tannin from the bark of *Bruguiera gymnorhiza* and *Rhizophora stylosa* is preferred as dye for *tapa*. The colours of *tapa* are generally limited to brown, black, yellow and red. Soot from burnt candlenut is used for black, turmeric for yellow and clay for red.

Bruguiera gymnorhiza (Rhizophoraceae) is a moderate-sized mangrove tree that grows to 15 m, occasionally up to 30 m tall. It has short buttresses and characteristic knee roots. Bark is pale brown to grey and slightly fissured. Leaves are simple, opposite, leathery and dark green with long leaf stalks. Flowers are single and axillary in position. Calyx is typically reddish with 10–14 pointed lobes. Petals are orange-brown in matured flowers and bi-lobed with each lobe having 3–4 long bristles. Hypocotyls are cigar-shaped, 15–25 cm in length, 2 cm in diameter and stout with blunt apex. When mature, they are reddish-brown or greenish-red. The species is shade-tolerant and seedlings may grow under full forest canopy. [Sources: Allen & Duke, 2006; Selvam, 2007; Giesen et al., 2007]

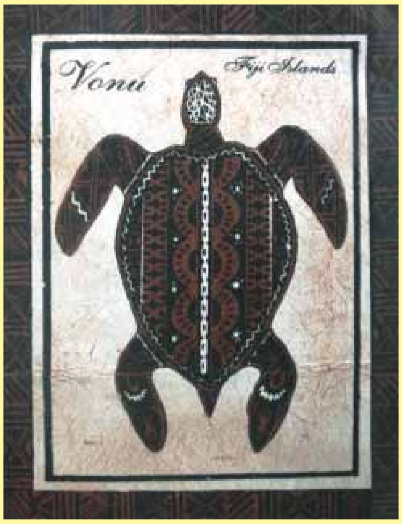
Photo: Hung Tuck Chan

Photo: Shigeyuki Baba

Photo: Shoko Yamagami

Bole and bark (left), flowers (middle), and propagules (right) of *Bruguiera gymnorhiza*.

Best known in Tonga, Fiji and Samoa, *tapa* is a traditional textile, which is used during religious rites and as ceremonial gifts (Day, 2000; Rohorua & Lim, 2006). However, most of the *tapa* produced today is sold as souvenirs for the tourist trade. Made from the bast (inner bark) of paper mulberry (*Broussonetia papyrifera*) trees, the strips of fibre are dried, soaked and pounded with mallets until they become wide and flexible (Day, 2000; Rohorua & Lim, 2006; Whistler & Elevitch, 2006; Singh, 2008; Larsen, 2011). A number of strips are then felted together to form a fine white cloth. The cloth is then painted or printed with decorative designs that vary from representations of plants and animals to geometric motifs.



Photos: Mami Kainuma

Tapa cloth from Fiji showing their dark brown colours of mangrove dye.

Eco-batik, Indonesia

Batik dyeing involves the use of wax to resist the dye from penetrating certain areas of the fabric. Melted wax is applied to the cloth before it is dipped in dye. Several colours are used, with a series of dyeing, drying and waxing steps to create exquisite batik patterns.

In Surabaya, Java, Indonesia, the local people produce eco-batik using mangrove dye (Januar, 2009; Chandra, 2011). Flowers of *Bruguiera gymnorhiza* are commonly used as red dye. Beside mangrove flowers, other plant parts such as roots, bark, leaves and propagules can also be used. Designs include motifs of mangrove plants and animals. This new and eco-friendly technique of making batik was developed and promoted by Lulut Sri Yuliani. It is unique and helps to preserve the mangrove ecosystem. The local people, who formerly felled mangrove trees for a living, are now collecting flowers to be sold for batik making.

Photo: Feniwati Chandra

Various designs of mangrove batik from Surabaya, Indonesia.

Bark for Tanning

Fishing nets, India

In the Godavari delta of Andhra Pradesh, India, the bark of *Ceriops decandra* is valued for its dye for tanning fishing nets (Dahdouh-Guebas et al., 2006; Raju et al., 2008). Even though most fishing nets are made of nylon, 47% of the fishermen continue to dye their cotton nets the traditional way using the bark of *Ceriops decandra* (Dahdouh-Guebas et al., 2006). About 2 kg of bark are boiled in water to create a red dye to preserve and increase the durability of cotton fishing nets. Dyeing is done once or twice a month.

Rich in tannin with content of 68–75%, the bark of *Ceriops decandra* yields a brown coloured dye, which the fishermen use to preserve cotton fishing nets (Raju et al., 2008). New cotton nets used once or twice are subsequently dyed. The traditional process of extracting tannin and dyeing fishing nets is as follows:

- Poles and branches of *Ceriops decandra* are soaked in water for 5–10 minutes before their bark is removed by manual beating with a wooden mallet.
- The bark flakes are collected, sun-dried and stored for use when needed.
- The stored bark (1 kg) is boiled in a pot of water (6 litres) for 2 hours, yielding 4 litres of dark red extract.
- After boiling, the bark residue is filtered and the dye solution is ready for use.
- Nets are soaked in the dye solution, sections at a time, for about 30 minutes before they are dried in the sun.

About 4 litres of dye extract is required to treat a cotton net, which can be used 4–5 times in a span of two months before re-dyeing (Raju et al., 2008). Regularly treated nets have a lifespan of two years. Fishermen in the Godavari delta use cotton nets in the backwaters and nylon nets in the open sea. Cotton nets are inexpensive and easy available as they are made locally, while nylon nets are expensive and not readily available. Even with the need for regular treatment, the cost of purchasing and operating cotton nets is about 23% cheaper than nylon nets.

Ceriops decandra (Rhizophoraceae) is a small mangrove tree reaching 15 m tall with a brown, smooth to flaky bark. Leaves are elliptic-oblong and glossy green. Flower heads are dense with 2–4 sessile flowers. Petals are white with hairy fringes. Fruits are ovoid-conical with dark red collars, and hypocotyls are club-shaped, ridged and curving upwards (a characteristic feature of the species). [Sources: Kitamura et al., 1997; Giesen et al., 2007; SFD, 2010]

Photo: Shigeyuki Baba

Photo: Katsuhiro Ono

Leaves and flowers (left), and propagules (right) of *Ceriops decandra.*

Fishing nets, Pacific Islands

In the early years, fishing nets used in the Pacific Islands were made from cotton (Van Pel, 1956). To preserve the longevity of these nets, which last only several months, fishermen would tan them with dye from the bark of mangrove trees. The tannin content of the dye varies between species and localities. The best grade of tan bark for dyeing cotton nets comes from *Rhizophora mucronata* and *Ceriops decandra* with 29% tannin content. Bark removed from cut branches are dried in the sun and stored.

The tanning process is simple (Van Pel, 1956). Firstly, the bark is chopped into small pieces and soaked in fresh water for 24 hours (1:3 v/v). The water containing the bark is then boiled for 1.5 hours, after which the tanning solution is ready for use. The nets must be clean and dry when immersed in the tanning solution for 12 hours before they are taken out to dry. The nets are then dipped again in the solution for another 12 hours. A net that is used every day for a few hours should be tanned every month. If it is in the water daily for 6 hours or more, tanning should be done every fortnight. Although the tanning solution can be used several times with more water and bark being added, it is best to prepare enough for immediate needs. A new net tanned for the first time turns brown. After being tanned several times, it becomes dark brown. With proper care and maintenance, tanning can triple the lifespan of nets.

Leather, Guyana

In Guyana, the bark of *Rhizophora mangle* is commonly used for tanning leather (Van Andel, 1998; Allan et al., 2002). Harvesting is done by Amerindians at the Waini river mouth in the north-western part of the country. Trees are selectively felled and debarked. A tree yields an average of 200 kg of bark and each harvester supplies up to 2,000 kg of bark per month. The bark is collected and sold in bundles to middlemen in Mabaruma who then ferry it to tanneries in Georgetown, the capital city, where tannin is extracted for tanning leather.

The majority of tanned leather produced is from cow hides, with about 10% from sheep hides (Allan et al., 2002). Over 5 kg of bark are used to tan each cow hide or two sheep hides. It has been reported that Guyana produces some 200 tanned hides per week. Although the supply of mangrove bark is getting scarce, tanners still prefer mangrove tannin over other tanning agents as it give a better colour and natural look to the leather.

Wine Additives

Tuba, Philippines

The bark of *Ceriops tagal* (*tangar*) in Sabah, Malaysia, was previously exported to the Philippines via consignment by ferry service between Sandakan and Cebu City (Chan & Salleh, 1987). Graded by colour, fresh light brown bark fetched higher prices than seasoned bark. Since 2001, the harvesting of *tangar* bark has been prohibited in Sabah (Tangah, 2005) but the stripping and smuggling of the bark by illegal immigrants continue.

Ceriops tagal (Rhizophoraceae) is a small mangrove tree that grows to 6 m in height. The species has short buttresses and knee-like breathing roots. The bark is pale greyish-brown, smooth in young trees and deeply fissured in old trees. Leaves are simple, shiny, opposite, ovate, and dark green in shade and bright greenish-yellow in full sun. Leaf apex is rounded or notched. Inflorescences are a condensed cyme and axillary with 5–10 flowers. Calyx is deeply sunken and divided into five green lobes. Petals are five in number and white turning brown, two-lobed and ending in 2–4 bristles. Fruits are ovoid with yellow collars, and hypocotyls are pendulous, slender, yellowish-green, warty, ribbed and pointed. [Sources: Duke, 2006; Selvam, 2007; Giesen et al., 2007]

In the Philippines, *tuba* from the inflorescence sap of coconut is a popular drink among the coastal communities (FAO, 1998; Sanchez, 2008). Fresh *tuba* is sweet, oyster-white in colour and contains 2–4% alcohol. It is fully fermented after 6–8 hours and has a shelf-life of 24 hours. It becomes acidic due to fermentation and is no longer acceptable as an alcoholic drink. By adding the bark of *Ceriops tagal* (*tangal*), the oyster-white tuba turns reddish-brown with a slight bitter and astringent taste. *Tuba* with *tangal* is less acidic, has 10–14% alcoholic content and can be kept for several months, if properly packaged.

The reddish-brown ground bark of *Ceriops tagal* has a tannin content of 20–40% (Hughes & Sukardjo, 1991; Maundu & Bandeira, 2005). Its tannin content of 37% is the highest among 10 mangrove species (Achmadi & Choong, 1992). When added into *tuba*, the tannin of the bark functions as a preservative by retarding the fermentation process and controlling spoilage microbes (Sanchez, 2008).


Photos: Hung Tuck Chan

Photo: Sabah Forestry Department

Photo: Hung Tuck Chan

Tree (top left) and bark (top right) of *Ceriops tagal*, illegal harvesting of *tangar* bark in Sabah (bottom left), and reddish-brown ground bark used as preservative of *tuba* in the Philippines (bottom right).

In Leyte, a concoction of *tuba* and coke has become a popular drink among the local people (Rodell, 2002). In Batangas, distilled *tuba* is drunk with coke as chaser (Schiefenhovel & Macbeth, 2011). It has been reported that *tangal* bark is used as an ingredient for processing a beverage similar to coke (Novellino, 2000). However, no details are available.

Aguardiente Especial, Ecuador

Aguardiente or 'fiery water' is a generic term for alcoholic beverages that contain 29–60% alcohol in Latin America (eNotes, 2012). Produced from sugar cane, *aguardiente* is the national liquor of Ecuador as it is most commonly consumed. Usually unflavoured, it is a clear colourless spirit. Every province in Ecuador produces its own *aguardiente*. A particular brand produced by *Frontera* in Manabi called *Aguardiente Especial* (48% alcohol content) has pneumatophores of *Avicennia germinans* immersed inside each 0.75 litre bottle. Unlikely to possess any medicinal properties, the pneumatophores probably serve as a source of tannin, which leaches into the liquor. Mangrove tree roots are known to contain tannin, which plays a role in the detoxification of excess iron and hydrogen sulphide in the soil (Kimura & Wada, 1989). The

Photo: Shigeyuki Baba

Aguardiente Especial, a liquor from Ecuador with pneumatophores of *Avicennia germinans*.

use of pneumatophores of *Avicennia germinans* as colorant of alcoholic beverages is indeed very special as reflected in the brand name, *Aguardiente Especial*. The brown coloured liquor resembles immature brandy and has a moderately smooth taste.

Fodder and Forage

Fodder, India

The state of Gujarat in India has about 1,650 km of coastline with 911 km^2 of mangroves (Hirway & Goswami, 2004; GIDR, 2010). About 90% of the mangroves are located around the Gulf of Kachchh with *Avicennia marina* being the dominant species.

Avicennia marina (Avicenniaceae), a mangrove tree that can grow up to 10 m tall. It produces numerous erect pencil-like pneumatophores with lenticels. The bark is greenish-grey, mottled and peeling in patches. Leaves are elliptic-oblong, pale green on the lower surface with acute to round apex. Inflorescences are a dense spike bearing 8–14 flowers with yellow to orange petals. Fruits are greyish-green and heart-shaped with an apex that is rounded or having a short beak. [Sources: Kitamura et al., 1997; Giesen et al., 2007]

An important use of mangroves to the coastal populations in Gujarat is for fodder (GIDR, 2010). The foliage of *Avicennia marina* is used as cattle feed. Propagules are also collected and fed to the calves. Collection is done mostly by the womenfolk, notably in Dandi (90%), Tadatalav (86%) and Ashirawandh (76%). Mangrove fodder is of high economic value to villagers engaged in livestock rearing such as those in Ashirawandh (94%), Lakki (82%) and Tadatalav (72%). More than 90% of the households reported that they increasingly harvest mangrove leaves as fodder for their cattle. This has enabled them to make significant savings from having to buy fodder from the market. Livestock owners also noted an increase in milk production, which rendered them income gains from increased sale of milk.

Photos: Shigeyuki Baba

Photos: Bharat Jethva

Photos: Shigeyuki Baba

Women harvesting foliage from *Avicennia marina* bushes in Gujarat as fodder for cattle (top row), washing foliage in a stream before returning home (middle row), and feeding cattle with foliage and calves with propagules (bottom row).

Most of the households in the districts of Kachchh (90%) and Jambusar (65%) own livestock (Hirway & Goswami, 2004). Livestock owners in Ahmedabad (100%), Kachchh (92–98%) and Bharuch (78–95%) use mangroves as fodder. They prefer mangrove fodder because it is easily available and free. It improves milk production and the animals like to eat it. The use of mangrove fodder is the highest during the summer and winter months. Villagers usually take up to an hour to reach the mangrove sites by foot. The collection usually starts in the morning and continues for 4–5 hours only as they have heavy loads of foliage to carry and long distances to walk back. Both men and women are engaged in the collection of fodder. Frequently, children also participate in the collection. During the rainy season when the mangroves become inaccessible, people turn to other fodders.

Grazing by cattle is usually not possible in the mangroves due to muddy site conditions (Hirway & Goswami, 2004). Cattle owners usually cut mangroves and feed them at home. The Maldharis are tribal nomads of Gujarat with large herds of camels and cattle. Their camels can easily move into mangrove areas during low tide to forage. Grazing by the camels can damage large mangrove areas, as their feet trample the pneumatophores and their saliva results in stunted growth of mangroves. Local communities are often helpless in regulating their access to the mangroves, as they have no control over these areas and repeated droughts have aggravated the problem. Encroachment of camels in the mangroves is rampant in villages of the districts of Ahmedabad and Bharuch.

Experiments on harvesting of *Avicennia marina* foliage for animal fodder showed that removal of leaves of the top half of plants, at a frequency of 3–4 times a year, did not have any adverse effects on re-growth and survival (Hoshino et al., 1988). However, total defoliation of plants would result in mortality and loss of vigour to recover.

Forage, Middle East

In the Red Sea and Gulf of Aden, mangroves of purely *Avicennia marina* serve as livestock forage for camels (PERSGA, 2004). Camel browsing has become a major problem causing degradation of the mangrove stands. The severity of browsing depends on the size of camel herds present in the area, site accessibility and the availability of other pastoral resources. Where heavy grazing occurs, adverse impacts on the mangroves include considerable reduction in crown size and restricting tree growth to stunted multi-stemmed bushes. Trampling of seedlings and pneumatophores by camels has been observed. In severely affected areas such as Al-Harounia and Ibn Abbas in Yemen, Haydob in Sudan and Khor Angar in Djibouti, heavy browsing by large herds of camels is aggravated by cutting of mangrove trees by the local people for fuel wood. Outer fringes are often severely browsed and cut. The cutting of trees in interior areas creates accessibility to camels, which gradually degrades the entire mangrove stand.

In Egypt, the Bedouins own camels and goats that feed on *Avicennia marina* foliage (Spurgeon, 2002). The species is an important food source for these animals, particularly in times of drought, when vegetation in the wadis dies off. Camels and goats wander freely to browse in the mangrove stands. In addition, some local people harvest mangrove leaves as fodder to feed their camels. Information on the numbers of camels and goats that feed on mangrove leaves or on the amount of foliage consumed is lacking.

Photos: Emad Al-Aidy

Camels browsing foliage of *Avicennia marina* in Egypt.

It has been reported that leaves of *Avicennia marina* are deficient in energy and protein as well as minerals such as copper, zinc, manganese and selenium (Faye et al., 1992a, 1992b). Camels feeding primarily on mangrove foliage suffered from malnutrition, low reproductive performance and high post-natal mortality. However, a study showed that the protein content of *Avicennia marina* leaves from the Red Sea coast was twice that of *Rhizophora mucronata*, with comparable values in lipid, carbohydrate and ash contents (Khafaji et al., 1993). Protein content of *Avicennia marina* leaves was 1.8 times higher than stems and 3.3 times higher than roots (Table 4.1).

Forage and fodder, Pakistan

In the Indus delta of Pakistan, some 16,000 camels and 11,000 cattle feed on mangrove foliage (Khalil, 1999, 2000). Each year, during the onset of the flood season (June to July), camels from the interior of Sindh would migrate to the mangrove forests in herds and stay in the mangrove areas until October (IUCN, 2005). In addition, camel farming is a major occupation of the well-known local tribe known as *Jat* who sells the camels within the country and to the Middle East. The camels sold within the country are used for transporting goods between the remote areas and nearby coastal towns of the Indus delta. Annual camel fairs are organised in Sindh and buyers from the Middle East would come to purchase camels from the *Jat* villages.

In the Indus delta, *Avicennia marina* leaves are also used for animal fodder (Khalil, 1999, 2000; Amjad et al., 2007). Households would purchase or collect mangrove leaves to feed their domestic animals. On average, each animal eats 3.8 kg of fodder daily. The total consumption of mangrove fodder has been estimated to be over 2,000 tonnes per year. The fodder is either directly fed to the cattle or is mixed with wheat straw and other cattle feed (IUCN, 2005). Along the Korangi-Phitti creek, villagers have developed a system of harvesting foliage in rotation and the managed forest resembles a tea plantation.

Honey and Wax

Wild honey and wax, Bangladesh

The Sundarbans in Bangladesh is one of the most fascinating places of the world where honey hunting maintains its historical traditions and importance (Burgett, 2000). Occupying an area of about 10,000 km^2, the Sundarbans is home to the giant honey bee *Apis dorsata*. There is an annual migration of thousands of colonies into the Sundarbans, beginning in December and continuing until January and February. Because mangrove tree species do not grow to great heights, *Apis dorsata* builds its large, single-comb nests relatively close to the ground, and are therefore accessible to the honey hunters.

In the Sundarbans, some 2,000 honey collectors (*Mowalis*) would go on their odyssey in April and May (Burgett, 2000; Kabir & Hossain, 2007). The main period of honey production is from April to June, and nectar is obtained mainly from *Aegiceras corniculatum*, *Ceriops decandra*, *Sonneratia apetala* and *Xylocarpus moluccensis*. Before entering the forest, the honey hunters must obtain permits from the Forest Department, which sets quotas of 78 kg for honey and 20 kg for wax per hunter. The honey harvested from the Sundarbans accounts for 50% of all the honey produced in Bangladesh. The honey is sold locally for USD 2–3 per kg and the wax sells for USD 3 per kg. The annual production of honey and wax has been estimated to be 200 and 50 tonnes, respectively.

Table 4.1 Nutritional composition (%) of different plant parts of *Avicennia marina* and *Rhizophora mucronata* (Khafaji et al., 1993)

Plant part	*Avicennia marina*				*Rhizophora mucronata*			
	Protein	Lipid	Carbohydrate	Ash	Protein	Lipid	Carbohydrate	Ash
Leaf	12.9	11.0	52.1	15.1	6.30	12.8	45.6	13.7
Stem	7.17	6.75	38.6	9.33	2.82	7.01	36.7	10.9
Root	3.96	7.65	36.0	12.2	2.33	8.44	35.0	9.85

Honey hunting in the Sundarbans often takes on a festive mood (Basit, 1995; Kabir & Hossain, 2007). The *Mowalis* come from different localities in boats to designated areas. Each group has 6–8 members including a leader for overall supervision. In the forest, they scout in strips in search for honey. Once a honeycomb is spotted, the other members would be alerted. Bundles of *Phoenix paludosa* leaves are then prepared and ignited as torches to smoke away the bees, allowing the *Mowalis* an opportunity to climb the tree and collect the combs. In the process, they suffer from bee stings but many are immune to the pain.

On a good day, the hunters can harvest 7–8 eight hives (Lawson, 2003). But it is hard work, having to trot in knee-deep mud, and to cross creeks and streams, while remaining fully alert of the ever-presence of the tiger. Every year, some 10–15 *Mowalis* are attacked by tigers during the honey-hunting season.

Photo: Pradeep Vyas

Photo: Mike Burgett

A group of honey hunters (*Mowalis*) (left) and hive of *Apis dorsata* (right) in the Sundarbans.

No processing is done in the field and the honey, still in combs, is sold to traders in nearby communities (Basit, 1995). In some cases, traders would come and buy the unprocessed honey. Some collectors have prior arrangements with traders in terms of cash advance.

In honey hunting, the bee colony is killed to harvest the honey combs (Field, 1995). Surviving bees of raided hives are left without their combs. Recovery is dependent on the vigour of the bee population and their capability to create new colonies.

Cultured honey, Vietnam

Beekeeping has become an important occupation of the local people in the provinces of Nam Dinh and Thai Binh in the Red River delta of northern Vietnam. Honey production is dependent on the flowering seasons of trees. Honey production is the highest during spring months of March to May as bees can feed the abundant pollen resources from fruit trees and cash crops planted in the communes (CORIN-Asia, 2009b).

Photos: Tran Sen Thi Mai

In Vietnam, boxes of bee hives transported to the coast of Nam Dinh and Thai Binh are kept under shade (top left), bees are released to forage in the mangroves (top right), bees form combs in the hives (bottom right), and honey is extracted from the combs (bottom left).

During the summer months of June to September, the farmers would move their bee hives to the coast where mangrove forests occur. Mobile programs have been formally organised to transfer bee boxes to mangrove forests during summer time. Nam Dinh and Thai Binh have 65 and 50 km of coastline with 4,000 and 4,200 hectares of mangroves, respectively (Tri et al., 2003). The Xuan Thuy National Park (XTNP), the first Ramsar site in Vietnam, is located in Nam Dinh. Covering a total area of 5,600 hectares, XTNP has 3,500 hectares of mangrove forests (Macintosh et al., 1999). In the coast, the bees would forage on *Aegiceras corniculatum* and *Kandelia candel* when these two species come into flower sequentially from July to September (Hong & San, 1993; Tri et al., 2003). The potential yield of honey has been estimated to be at least 0.2 kg per hectare annually. It has been reported that honey production is three times higher when the hives are moved to the coast compared to inland hives (CORIN-Asia, 2009c).

Honey production in Nam Dinh has increased significantly. Total yield in 2008 reached 450 kg, generating a total revenue of USD 1,440 (CORIN-Asia, 2009b). This reflected a significant improvement since its establishment in 2004 when the production was only 200 kg worth USD 240. In 2008, honey production was 280 kg from March to May, 100 kg from June to August and 50 kg from September to November. Yield during the winter months of December to February was the lowest with only 20 kg of honey produced.

Honey production, Caribbean

In Florida, the main species for pollen and nectar production are *Avicennia germinans*, *Conocarpus erectus* and *Laguncularia racemosa* (Bradbear, 2009). Many beekeepers would transfer their hives from the citrus plantations in central Florida to the mangrove areas. The mangrove honey season is from mid-May to early August. Average honey production from the mangrove is 35–40 kg per colony (Hamilton & Snedaker, 1984).

In Cuba, honey production remains an important and sustainable use of mangroves (Spalding et al., 2010). Some 40,000 hives are moved into the mangroves along the south coast during the four months of *Avicennia* flowering, producing 1,700–2,700 tonnes of honey per year.

In Guyana, there are about 300 beekeepers, with some 2,000 hives (Narine, 2010). Beekeepers locate their hives near mangrove areas during the onset of the honey season from May to August. The average production of mangrove honey is 25–30 kg per colony.

Handicrafts and Ornaments

Mah Meri woven products, Malaysia

On Carey Island in Selangor, Malaysia, the womenfolk of the *Mah Meri* aboriginal tribe at the village of Sungai Bumbun are well-known for their indigenous handicrafts. While the men carve unique wooden sculptures and masks, the women weave exquisite products from leaves of *Pandanus odoratissimus* (*mengkuang*) and *Nypa fruticans* (*nipa*) (Rahim, 2007).

> *Pandanus odoratissimus* (Pandanaceae) grows up to 15 m in height. Plants are erect and coarsely branched resembling a candle-stick holder. Stems are usually pale greyish-brown, hollow, ringed by leaf scars and produce prop roots. Leaves are sword-like and arranged spirally in clusters. The leaf apex is long and flagella-like. Under exposed conditions, leaves hang downwards giving the plants a characteristic drooping appearance. At the base of the underside of leaves are two clearly demarcated dull green stripes, one on either side of the midrib. Leaf margin and midrib are prickled. The species is dioecious with male and female flowers occurring in separate plants. Male flowers are tiny, white, fragrant and last only for a day. Female inflorescences are free or joined carpels. Fruits, resembling pineapples, are globular with tightly bunched, wedge-shaped fleshy drupes. They are green when young and orange-red when ripe. Ripe fruits are eaten raw, drank as juice and used in various food preparations. An important food crop of the Pacific Islands, the species occurs in groves along sandy and rocky shores. [Sources: Selvam, 2007; Chan & Baba, 2009]

Photos: Hung Tuck Chan

Pandanus odoratissimus (*mengkuang*) is planted in Sungai Bumbun (top), and exquisite *Mah Meri* purses and pouches are woven from the leaves (bottom row).

Assisted by the Centre for Orang Asli Concerns, a cooperative named *Topoq Topoh*, was formed in 2005 to help the *Mah Meri* women undertake weaving as their traditional culture (Persoon et al., 2007). The project provides the women with an occupation that would supplement their family earnings. The women began planting *mengkuang* since 2004 to replenish the dwindling resource on the island.

Today, the *Mah Meri* women weave purses, pouches, mats and baskets from *mengkuang* leaves (Rahim, 2007). *Mengkuang* leaves are processed before weaving. Harvested leaves with their spines removed are laid out to dry in the sun or over embers until they are beautiful beige in colour. The dried leaves are then cut into fine strips before boiling in natural dyes of various colours. Using traditional weaving techniques, the dyed leaf strips are coiled, plaited, twined and woven into exquisite products such as mats, baskets, purses, pouches, etc. Simple pouches take about three days to weave while more elaborate mats can take up to several weeks. The durability and flexibility of the strips enable the woven products to be of good quality, and in different shapes and sizes (MAP, 2007). The women also weave decorative items (resembling Japanese origami) from *nipa* leaves for spirit huts, altars, homes and dancers (Rahim, 2007). *Nipa* leaves are easier to weave than *mengkuang* leaves as they do not need any processing. A bi-coloured effect of yellow and green is obtained by weaving and plaiting strips of young and mature leaves.

Photos: Hung Tuck Chan

Young *Mah Meri* women busy weaving *nipa* leaves for the Ancestors' Day celebration (top row), and decorative items woven from *nipa* leaves for dancers and prayers (bottom row).

The *Mah Meri* people at Sungai Bumbun celebrate *Hari Moyang* (Ancestors' Day) a month after the Chinese New Year each year (Rahim, 2007). The morning begins with rituals and prayers in honour of their ancestors at the spirit hut. Music and dances then follow with the male dancers wearing their carved masks and the female dances wearing their elaborate woven *nipa* ornaments. After the dances, there is a pot-luck lunch for all present including guests and visitors, and all celebrations at the spirit hut end at noon. *Hari Moyang* is a major celebration for the *Mah Meri* people on Carey Island who take a three-day mandatory holiday.

Photo: Mana.my

Mah Meri female dancers wearing their ornaments made from young and mature *nipa* leaves during the Ancestors' Day celebration.

Pandanus handicrafts, Pacific Islands

Pandanus tectorius play an important role in everyday life in the Pacific (SPC, 2006). In Kiribati, the plant is called the 'tree of life' and in Marshall Islands, it is called the 'divine tree'. Among the many uses of the species is the weaving of leaves into various products.

Pandanus tectorius (Pandanaceae) resembles *Pandanus odoratissimus* in appearance and morphology. Having features of a multi-stemmed candlestick-holder with numerous prop roots, the species is comparatively smaller in stature. Prop roots can emerge from the upper part of the trunk and leaf spines are smaller and greenish. Leaves of *Pandanus odoratissimus* have two strips at the base, one on either side of the midrib. No such feature is observed in *Pandanus tectorius*. Both species are closely related taxonomically and can hybridise where they co-exist. [Sources: Thomson et al., 2006; Selvam, 2007]

Pandanus tectorius is distributed throughout the Pacific Islands (Arbeit, 1990). However, plants used for weaving are usually cultivated in the premises of the artisan's home. They are carefully tended, pruned, and replanted to keep the leaves long, unbent and healthy. The weaving of leaves is done only by the women. Leaves are usually collected green, and their thorns removed before drying in the sun. Sometimes, the leaves are soaked for several days in seawater. In other places, leaves may be boiled in fresh water to make them lighter in colour and softer. Once the leaves have been prepared, they are rolled into flat coils and stored. Just before use, the leaves are made supple and cut into fine strips. The most common method of weaving is plaiting using tanned or dyed leaves.

Photos: Shigeyuki Baba

Leaves and fruit of *Pandanus tectorius* (left), and weaving of leaves (right) in Kiribati.

In the Marshall Islands, the womenfolk are considered the finest weavers (Mulford, 2006). Mats, bags and hats woven from leaves of *Pandanus tectorius* are a traditional part of Marshallese lifestyle. The material is obtained from dried brown leaves and fresh green leaves. Dried brown leaves are collected from the plant, removed of their thorns, flattened and kneaded to soften them. Fresh green leaves are collected, removed of their thorns and dried in the sun for several days. Before weaving, the dried leaves need to be stripped into thin sections and the rough inside surface removed. The simple one-over and one-under technique of weaving offers many design possibilities. Patterns are also created by combining natural and dyed strips of leaves. Crafts made today are mainly for the tourists, but they reflect the past as the same traditional materials and techniques are used.

Photos: Judy Mulford

Weaving of mats from leaves of *Pandanus tectorius* in the Marshall Islands.

Garlands and leis, Pacific Islands

Flowers of *Bruguiera sexangula* are used in Hawaii as leis (Allen, 1998). In Tonga, garlands are made from flowers of *Bruguiera gymnorhiza* and *Lumnitzera littorea* (Steele, 2006). Flowers of *Bruguiera gymnorhiza* in Samoa, and flowers of *Rhizophora mangle* and *Rhizophora stylosa* in Fiji are used as garlands. In the Pacific Islands, garlands and leis are also made from the fragrant flowers and fruits of *Pandanus tectorius* (Thomson et al., 2006).

Photo: Shoko Yamagami

Photo: Sandy Ao

The bright red flower calyx of *Bruguiera gymnorhiza* (left) can be chained together as garlands (right) .

Fishing using Plants

Brush parks, Sri Lanka

In Negombo lagoon, Sri Lanka, brush parks (*mas athu*) are widely used as fish-aggregating devices (Samarakoon, 1986; Costa & Wijeyaratna, 1994; Amarasinghe et al., 2002). Defoliated branches and twigs of mangroves are arranged, vertically or slightly inclined, in a circular patch in the lagoon at depth of less than 1.5 m. More than 3,000 brush parks have been constructed in the lagoon (Costa & Wijeyaratna, 1994). Brush park fisheries contribute about 36% of the total fish catch. Each fisherman can operate 3–20 brush parks, varying from 6–12 m in diameter (Amarasinghe et al., 2002). During harvesting, a net is used to encircle the brush park, the branches are removed and the fish enclosed are harvested by a scoop net. With every harvest, a new brush park is constructed to replace the existing one.

Locally, there are 14 mangrove species with *Rhizophora mucronata, Bruguiera gymnorhiza, Lumnitzera racemosa* and *Avicennia marina* being dominant (Costa & Wijeyaratna, 1994). Although all species are used, studies have shown that brush parks constructed from branches and twigs of *Avicennia marina* had the highest fish yield. Those constructed with *Excoecaria agallocha* and *Sonneratia caseolaris* yielded the lowest.

An investigation of 116 brush parks in Negombo lagoon showed that the mean annual fish yield was 12.5 tonnes per hectare (Amarasinghe et al., 2002). Fin fish form about 90% of the yield with shrimp and crabs forming the rest. Fish yields show considerable seasonal variations, which may be attributed to seasonal water salinity variations in the estuary. Low rainfall and low freshwater input allow the inundation of seawater, which promote the recruitment of fin fish and shrimp into the estuary.

New brush parks are constructed at least 100–200 m from existing ones, perhaps to minimise catch competition (Amarasinghe et al., 2002). Other site criteria for brush parks are moderate water currents, muddy bottoms and proximity to outflow channels. Based on traditional knowledge of the local fishermen, the choice of mangrove species is dependent on the type of catch. Branches and twigs of *Excoecaria agallocha* are used to catch ornamental fish, while branches and twigs with intact leaves are used mainly to catch shrimp. As brush park fisheries require intensive labour, the introduction of brush parks as a fishing method creates employment (Kapetsky, 1981). An important disadvantage is that large amounts of branches are needed to erect and maintain a brush park (Wijeyaratna & Costa, 1987). Since this wood is obtained from the mangrove forests on the shores of the lagoon, the resulting deforestation would lead to loss of vegetation, fish population as well as mangrove associated fauna.

Photo: Tharanga Sujeewa

Brush park with intact leaves for catching shrimp in Negombo lagoon, Sri Lanka.

Fern parks, Nigeria

In southwestern Nigeria, the use of the mangrove fern *Acrostichum aureum* as parks to catch shrimp is a new fishing technique adopted by the local fishermen in Lagos lagoon (Emmanuel, 2010). The catching of shrimp is confined to the rainy season from April to October when there is in-migration of shrimp from freshwater streams draining into the lagoon. Cheap to construct, the fern parks serve as sanctuaries for shrimp. Each park consists of a bundle to fronds tight together at the base using ropes. The apical ends of the fronds are trimmed. During harvesting, the shrimp are caught using a scoop net gently placed beneath the ferns and lifted up. The lifespan of each park is just two months before the fronds start to decay and sink in the water column. In areas with influx of organic matter, the parks appear to be more productive. With the market price of shrimp 24% higher than meat and 36% higher than fish, and with fronds of the fern readily available, shrimp fishing using *Acrostichum* parks in the Lagos lagoon shows promise.

Fish poisons, Pacific Islands

Seeds of *Barringtonia asiatica* have been used traditionally in Micronesia to stupefy fish (Cox, 1979; Merlin, 2002). Containing saponins, the seeds are pounded, pulped or grated, mixed with water and thrown into pools where fish is found. Dead or stunned fish and octopus rising to the surface are collected by hand, cooked and eaten with no apparent harm. *Derris trifoliata* and *Derris elliptica* are also used as fish poison in the Pacific Islands (Merlin, 2002). Containing rotenone, the whole plant is crushed and thrown into streams and reef lagoons to kill fish. In New Caledonia, seeds of *Cerbera manghas* and the sap of *Excoecaria agallocha* are also used as fish poisons (Veitayaki et al., 1995).

Barringtonia asiatica (Lecythidaceae) is a small- to medium-sized tree, growing up to 20 m tall. Leaves, spirally arranged in rosettes, are obovate, thick and leathery. Old leaves wither yellow. Borne on short erect racemes, flowers are large and sweet scented with greenish-white petals and showy white stamens with pink tips. Fruits are large, cubic and have a broad square base that tapers towards the tip, which carries two persistent calyx lobes. Green when young and yellowish-brown when mature, the fruit has a tough fibrous husk and contains one large seed. Borne on long slender pendulous spikes, *Barringtonia racemosa* flowers have white or pinkish stamens. Old leaves wither red. [Sources: Duke, 2006; Selvam, 2007; Giesen et al., 2007]

Derris trifoliata (Leguminosae) is a scrambling woody climber associated with mangroves. Stems are lenticellate and leaves are alternate with three ovate or elliptic leaflets. Occurring in drooping clusters, flowers are white or pale pink. Fruits are flat oblong pods bearing two seeds. [Sources: Giesen et al., 2007; SFD, 2010]

Photo: Hung Tuck Chan

Photo: Shigeyuki Baba

Photos: Hung Tuck Chan

Tree and fruits of *Barringtonia asiatica* (top row), and flowers and leaves of *Derris trifoliata* (bottom row).

In Tonga, fish-poisoning using the stems of *Derris elliptica* is widely used and is one of the few fishing activities where women regularly participate (Kirch & Dye, 1979; Dye, 1983). Seeds of *Barringtonia asiatica* are sometimes used. The favoured environment for poisoning is the reef flat. A seine net is set up to block escape channels, and pounded *Derris* stems placed in a small sack are shaken in the water beneath coral heads and reef rocks. Within minutes, stunned fish would rise to the surface or lie on their bottom where they are then speared, knifed or picked by hand.

An interesting account of fishing using leaves of *Derris* as poison by the fishing community at Guadalcanal in Solomon Islands was given by Rickard & Cox (1986). Leaves of the *Derris* vine are gathered in baskets and taken to a special preparation site where they are deposited into a hollow of a rock or coral outcrop and pounded with an equal amount of sand. A favourite technique is to pound the leaves in tandem with upward and downward strokes by two fishermen each using a pole. When the leaves have been macerated into a granular green paste, it is wrapped in leaves of various strand plants and the parcels are ready for use. A group of 2–4 fishermen would carry these parcels to the lagoon or reef. Sometimes a dugout canoe is towed along to store the parcels and their catch. On reaching the fishing site, a fisherman dives with a parcel of fish poison in his hand, trailing a green cloud behind him in the water. He then surfaces and awaits the sign of affected fish. Poisoned fish exhibit extreme disorientation, swimming in circles or spirals. Larger fish are speared immediately, while smaller fish are collected as they surface belly up. The majority of fish are 15–30 cm in length. Smaller fish appear to be more susceptible to the poison, as they usually die immediately. The effect of the poison on larger fish, however, is to merely stun and disorient them so that they can become easy prey for the diver.

The most common and widely used fish poisons are rotenone and saponin (Cannon et al., 2004). Although most countries no longer allow the use of piscicides in large-scale killing of fish, they are used to catch fish for food in certain areas of Africa, South America, the Philippines, and South Pacific. Rotenone kills fish by disrupting the exchange of oxygen (Veitayaki et al., 1995). Its effectiveness declines with exposure to sunlight, so it does not persist for very long in the environment. Saponin paralyses the gills of fish. Many of these piscicidal compounds also possess other biochemical activities. For example, the same plants that are poisonous to fish are also used in traditional medicine (Cannon et al., 2004).

One of the most serious problems associated with the use of plants as fish poisons is their non-selectivity (Veitayaki et al., 1995). The poisons kill many species of fish, both adults and juveniles. When all age classes of fish populations are removed from an area, stock depletion can easily result. If used on a small-scale and in a controlled manner, the use of fish poisons may not be harmful to the environment. However, if used in large amounts, repeatedly or indiscriminately in the same area, fish poisons could lead to the over-exploitation of fish resources. They also kill other organisms such as polyps of coral reefs.

Chapter 5

RECENT NON-WOOD PRODUCTS

Herbal Remedies

Herbal teas and extracts, Thailand

Traditionally, herbal remedies in Thailand have been used to treat infections, ailments and diseases. They are often consumed as teas, which are infusions of dried plant parts steeped in boiling water. Herbal remedies are also consumed as powdered extracts in capsules. Leaves of two mangrove species are commercially sold as herbal teas and extracts. Herbal companies such as Wanalee Co. Ltd., are exporting teas and extracts of *Acanthus ebracteatus* and *Pluchea indica* (TriSiam, 2011).

Acanthus ebracteatus (Acanthaceae) is a common mangrove herb that grows along the upstream banks of rivers and streams. The species produces aerial or prop roots, which compliment its sprawling habit. Growing in thickets, plants produce holly-like leaves with dentate margins and two spines flanking each leaf stalk. Under shade, leaves are without spines and margins become entire. Flowers, borne on terminal spikes, are white and showy. Flowers of *Acanthus ilicifolius* are pale blue. [Sources: Tomlinson, 1986; Duke, 2006]

Pluchea indica (Asteraceae) is an aromatic shrub. Leaves are sessile, alternate and pale green with fine-toothed margins. Flower heads are flat-topped with numerous violet flowers. Flowering occurs throughout the year. Considered a mangrove associate, the species occurs in clusters at the landward side of mangroves. It is commonly found on elevated habitats such as coastal bunds. [Source: Giesen et al., 2007]

Photo: Shigeyuki Baba

Photo: Hung Tuck Chan

Shrubs of *Acanthus ebracteatus* (left) and *Pluchea indica* (right).

Herbal tea of *Acanthus ebracteatus* relieves body aches, allergies, colds, low immunity, insomnia, infected wounds and fever (Cheeptham & Towers, 2002). Ethanol extract of *Acanthus ebracteatus* tea has antibacterial activity against *Staphylococcus aureus.* Tea brewed from the leaves of *Acanthus ilicifolius* relieves pain and purifies blood (Singh et al., 2009). From the aerial parts of *Acanthus ilicifolius*, lignan glucosides and flavonoid glycosides have been isolated (Kanchanapoom *et al.*, 2001, 2002). Screening of 13 types of herbal teas from Thailand showed that the antioxidant properties of *Acanthus ebracteatus* tea belong to the low category based on total phenolic content (Chan et al., 2011).

Herbal tea of *Pluchea indica* is good for diabetes and hemorrhoids (Cheeptham & Towers, 2002). It has antibacterial activity against *Bacillus subtilis* and *Staphylococcus aureus*. Leaves of *Pluchea indica* displayed strong antioxidant and tyrosinase inhibition activities (Vimala et al., 2006). Standardised antioxidant and skin-whitening extracts have been developed from *Pluchea indica* for use as health supplements and cosmetic products. Quercetin is a major phenolic compound isolated from the leaves (Traithip, 2005).

Herbal teas, Mexico

Residents from the fishing village of La Pitahaya in Mexico, consume a herbal tea made from leaves of *Avicennia germinans* (Hernández-Cornejo et al., 2005). The tea is believed to be effective in treating gastric disorders. Fishermen from villages in Teacapan-Agua Brava, Mexico, used to drink tea from the bark of *Rhizophora mangle* and *Laguncularia racemosa* to treat diabetes, kidney stones, skin diseases, and generally to improve kidney function and purify blood (Kovacs, 1999).

Mangrove teas, India

In India, mangrove teas have been produced in the laboratory from leaves of five mangrove species, namely, *Bruguiera cylindrica*, *Ceriops decandra*, *Rhizophora* x *annamalayana*, *Rhizophora apiculata* and *Rhizophora mucronata* (Kathiresan, 1995). Through a process of withering and fermentation, teas from mangrove leaves are rich in polyphenols such as theaflavins. Withering time of 12–18 hours yielded the highest theaflavin content. A toxicity trial conducted on albino mice showed no toxic effects, based on organ weights of control and experimental animals.

Acanthus tea, Indonesia

In Indonesia, a recipe for producing herbal tea from *Acanthus ilicifolius* has been developed (MAP, 2006). Leaves removed of their thorns are dried in the sun. The dried leaves are chopped into fine pieces and extracted using hot water to obtain the tea infusion, which is consumed as green tea. Some dried aromatic leaves of *pandan* (*Pandanus amaryllifolius*) can be added for aroma. *Acanthus* tea is believed to have anti-allergy properties, and can be used to treat boils, abscesses and kidney stones.

Minor Non-Wood Products

Vegetable supports, Malaysia

Some local villagers in Matang, Malaysia, used to gather the frond stalks of *Acrostichum aureum*, a mangrove fern that forms dense thickets in open forest areas (Chan & Salleh, 1987). Stalks (1.5–2.0 m in length) are cut, defoliated and sold in bundles to vegetable farmers as structural

Photos: Hung Tuck Chan

Acrostichum aureum forms dense thickets in disturbed forest sites (left), and its stalks were harvested in Matang and sold to vegetable farmers (right).

supports for their climbing vines. Such an enterprising and ingenious use should be encouraged since these ferns are considered a forest weed by foresters as they tend to stifle the natural regeneration of preferred mangrove tree species. It is unfortunate that this use of the fern is no longer viable due to poor demand by vegetable farmers.

Village bio-fences, India

Since the Indian Ocean tsunami of December 2004, villagers of Puthuvypu in Kerala, India have planted trees of *Bruguiera gymnorhiza* as bio-fences (Krishnamoorthy et al., 2010). Besides providing shade, aesthetics and protection to the village, the bio-fences are growing with healthy natural regeneration.

Resort hedges, Belize

In the Cocoplum Resort at Maya Beach, Belize, mangroves have been planted along lagoons and canals (WWF, 2009). Tree of *Rhizophora mangle* and *Conocarpus erectus* are pruned as low hedges, providing a natural buffer for shoreline stabilization. Aesthetically pleasing, the hedges attract wildlife, and represent an economical and environment-friendly alternative to sea walls for coastal protection. This effort won the World Wildlife Fund's Mangrove-Friendly Development Challenge.

Scenic ponds, Japan

In University of the Ryukyus, Okinawa, *Rhizophora mangle* trees are used as ornaments for landscaping ponds in the campus.

Seedlings as ornaments, Japan

On the southern islands of Iriomote and Ishigaki in Japan, sprouting *Rhizophora stylosa* plants are sold in souvenir shops to tourists.

Photo: Hung Tuck Chan

Photo: Shigeyuki Baba

Photos: Top Tropicals

In Japan, *Rhizophora mangle* tree forms the central theme of the pond in University of the Ryukyus in Okinawa (top), seedlings of *Rhizophora stylosa* are sold to tourists in Iriomote and Ishigaki (bottom left), which can be grown as bonsai (bottom right).

Pens as souvenirs, Kiribati

The International Society for Mangrove Ecosystems (ISME) has implemented a mangrove rehabilitation project in the Republic of Kiribati since 2005 (Baba et al., 2009; Chan & Baba, 2009; Baba, 2011). Funded by Cosmo Oil Company Ltd. Japan, and with the support from the Ministry of Environment, Land and Agriculture Development, and the Ministry of Education, Youth and Sports of Kiribati, ISME has established coastal green belts along the banks of causeways in Tarawa, with planting programs participated by school children and youths. Under the project, mangrove ballpoint pens were developed using propagules of *Rhizophora stylosa*. A hole was drilled into the basal end of each propagule and a ballpoint pen refill was inserted. This activity was aimed at demonstrating that useful products can be derived from mangrove plants.

Photo: Midoriko Nagasaki
Photo: Shigeyuki Baba

Ballpoint pens produced from propagules of *Rhizophora stylosa* in Kiribati.

Fodder for dairy cattle, New Zealand

The presence of salt in mangrove leaves is well-known. Their use as fodder for grazing livestock has been widely documented (e.g. Hong & San, 1993 for Vietnam; Scott, 1995 for Qatar; Hogarth, 2007 for Arabia and Pakistan; Lin & Fu, 2000 for China; Baba, 2004 for Iran; Spalding *et al.*, 2010 for Oman).

Recently, Maxwell & Lai (2012) reported for the first time feeding trials in Waikato, New Zealand, where dairy cattle were fed with foliage of *Avicennia marina* (leaves, twigs and sometimes propagules), fresh pasture (rye-grass plus two species of clover) and hay (saved from the summer). Three trials were conducted in 2008, 2010 and 2012. The protocols involved placing the herbage as fodder in a new paddock and the cattle had three choices of fodder. They had never seen mangrove foliage but had experienced pasture and hay many times before. Results showed that 49% of the cattle (n = 50) chose *Avicennia* during their initial encounter (first visit) with 37% and 14% choosing pasture and hay, respectively. Subsequent encounters (re-visits) showed even higher scoring for *Avicennia* (83%) than pasture (11%) and hay (6%). Based of these trials, it is evident that *Avicennia* foliage can be served both as feed and salt nutrient supplement for dairy cattle.

Photos: Gordon Maxwell

A feeding trial of *Avicennia marina* foliage as fodder for calves (left) and cattle (right) in a dairy farm, Waikato, New Zealand.

Hides for duck hunters, New Zealand

In New Zealand, duck hunting is a common recreational activity in the Whangamarino wetlands of Waikato (Cromarty & Scott, 1995). The mangroves of purely *Avicennia marina* fringing rivers and streams are popular sites used by the duck hunters. Most boating trips are related to duck hunting, although some local people engage in recreational fishing for eel and mullet. The hunting season begins in May and ends in July each year, and duck hunters take great pride in bagging the most number of ducks (Perkins & Gidlow, 2009). Ducks have remarkably good eyesight and hunters have to camouflage themselves in a hide (*maimai*). The purpose is to conceal the hunters while providing an open field for shooting. In recent years, some hunters have developed an ingenious way of constructing make-shift hides by camouflaging their boats using cut bushes of *Avicennia marina*, which are readily available.

Photo: Gordon Maxwell

Bushes of *Avicennia marina* are used by duck hunters as hides in New Zealand.

Chapter 6

MANAGEMENT IMPLICATIONS

Uses and Users

Mangrove forests are important ecosystems to human communities living in coastal areas. They provide for a wide range of wood and non-wood forest products. Coastal villagers, who are dependent on mangrove resources for their livelihood, possess a wealth of traditional knowledge. They recognise that different mangrove species have different properties, making some more suitable than others for specific uses. Such resource use is often sustainable, as it forms an integral part of the ecology and functioning of the ecosystem.

However, with population growth and increasing demand for forest resources, mangrove forests in some localities are showing various levels of degradation due to over-harvesting of forest products. In recent decades, large-scale commercial and destructive uses have led to extensive loss of mangrove forests.

Wood Products

One of the most common uses of mangrove forests is as a source of wood, primarily for fuel and construction. Many tree species, notably those of the family Rhizophoraceae, produce heavy hardwood that burns with a high calorific value. The wood is therefore highly suitable as fuel wood or for making charcoal. The harvest of mangrove fuel wood for domestic consumption and commercial markets is widespread throughout the tropics.

As mangrove wood is strong, durable and rot-resistant, they are well-suited for constructional use. The extraction of mangrove poles is mostly for the construction of houses and fish traps. They are in great demand as piles for building and road construction as the poles are extremely resistant to rot under anaerobic conditions. Mangrove wood is also used in boat building and for wood carving. In addition to wood for fuel and construction, mangroves have been an industrial source of pulp wood in recent years. Case studies on woodchip production in Malaysia for manufacturing rayon and cellophane in Japan, and on pulp and paper for newsprint production in Bangladesh, have shown that such extensive and destructive use is non-sustainable due to over-exploitation and depletion of wood resources. However, the industrial production of value-added commodities such as white charcoal and briquettes does show promise, provided that there are national efforts to establish mangrove forest plantations for such purposes.

Non-Wood Products

Mangroves are also an important resource for a wide range of non-wood forest products. The *Nypa* palm is widely used for the production of thatches, cigarette wrappers, beverage, sugar, wine and vinegar in Southeast Asia. Weaving of *Pandanus* leaves into useful products supports viable cottage industries particularly for the womenfolk in the Asia-Pacific region. Honey production is an important economic activity in countries such as Bangladesh, Vietnam, Cuba and Guyana. Mangrove foliage is used as fodder for cattle and camels, notably in India, Pakistan and the Middle East. The use of mangrove bark for tannin as dye for fabrics remains a viable economic activity in countries of Asia Pacific. Mangrove plants are also a source of herbal remedies for some coastal communities.

Non-wood forest products are vital in generating extra income for the coastal communities. Often, such industries do not require the felling of trees and hence do not degrade the forests. In fact, they require the sustenance of the forest ecosystem to ensure adequate and continued supply of raw materials. In this context, they can be considered as environment-friendly.

Sustainable Management

It is gaining acceptance that conservation, economics and social needs are not issues that can be dealt with separately (Barbier, 1987). In order to ensure sustainable management of ecosystems in a given area, the following goals need to be addressed:

- Ecological sustainability – maintaining genetic diversity, ecological resilience and biological productivity
- Economic sustainability – satisfying the basic needs of local populations and reducing poverty; enhancing equity through ownership, management and participation in economic activities; and increasing useful goods and services
- Social sustainability – maintaining cultural diversity; sustaining local institutions and traditions; ensuring social justice; and ensuring full participation through decision-making, employment and training

As mangroves have considerable socio-economic values to human communities living in coastal areas, there is an urgent need for their sustainable management, conservation and rehabilitation (ITTO, 2012). These values need to be communicated to seek public and political support. In some countries, lessons have been learnt, and efforts are made to protect and use mangroves and adjacent ecosystems sustainably.

The following authoritative manuals, guidebooks, work and action plans, guiding principles, and codes of conduct and practice, aimed at promoting the sustainable management and use of mangrove resources, are useful references:

- *Mangrove Forest Management Guidelines* (FAO, 1994)
- *Restoration of Mangrove Ecosystems* (Field, 1996)
- *Mangrove Action Plan for Sustainable Management of Mangroves 2004-2009* (ISME & ITTO, 2004)
- *Principles for a Code of Conduct for Management and Sustainable Use of Mangrove Ecosystems* (World Bank, ISME & cenTER Aarhus, 2005)
- *Study of Lessons Learned from Mangrove and Coastal Ecosystem Restoration Efforts in Aceh since the Tsunami* (Wibisono & Suryadiputra, 2006)
- *Mangrove Guidebook for Southeast Asia* (Giesen et al., 2007)
- *Mangrove Rehabilitation Guidebook* (GNF, 2007)
- *After the Tsunami: Coastal Ecosystem Restoration: Lessons Learnt* (UNEP, 2007)
- *Coastal Forest Rehabilitation Manual for Aceh Province & North Sumatra* (FAO, 2008)
- *Manual on Guidelines for Rehabilitation of Coastal Forests Damaged by Natural Hazards in the Asia-Pacific Region* (Chan & Baba, 2009)

The International Society for Mangrove Ecosystems (ISME) adopted a *Charter for Mangroves* to complement the *World Charter for Nature* endorsed by the General Assembly of the United Nations (ISME, 1991). As general principles in the charter, mangrove ecosystems that are utilised by people shall be managed to achieve and maintain sustainable productivity without degrading the integrity of other ecosystems with which they coexist. The sustainable utilisation of mangrove ecosystems by traditional users shall be recognised and provided for to improve the welfare of the indigenous people. The decisions affecting the management of mangrove ecosystems shall be made only in the light of best existing knowledge and an understanding of the specific location. In the charter, decisions on the use of mangrove ecosystems include the following considerations:

- Utilise the mangrove resources so that their natural productivity is preserved
- Avoid degradation of the mangrove ecosystems
- Rehabilitate degraded mangrove areas
- Avoid over-exploitation of the natural resources produced by the mangrove ecosystems
- Avoid negative impacts on neighbouring ecosystems
- Recognise the social and economic welfare of indigenous mangrove dwellers
- Control and restrict non-sustainable uses so that long-term productivity and benefits of the mangrove ecosystems are not lost
- Introduce regulatory measures for the wise use of mangrove ecosystems


Photo: S. Baba

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