Chapter 14
Mangroves in Myanmar

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Abstract The mangrove extent in Myanmar, according to the most recent forest resources assessment in 2020, has been estimated as 1.12 million acres. Among three main tracts of mangroves—Rakhine coastline, Ayeyarwady delta, and Tanintharyi coastline—the mangroves in the Tanintharyi coastline have now turned into the largest areal extent despite the fact that the Ayeyarwady delta had the largest in the past. With a large share of the Bay of Bengal Large Marine Ecosystem, coastal and delta ecosystems including mangroves, coral reefs, seagrass beds, beaches, and dunes largely flourish throughout the Myanmar coastline. In this context, the Tanintharyi coast showed the highest species diversity of mangrove flora while the least species diversity was observed in the Ayeyarwady delta. Provided that a total of ten prominent provisioning, regulating, supporting, and cultural services were considered, fishery nursery and habitat has shown its highest value in the mangrove ecosystem services, followed by coastal protection. In particular for the latter services of coastal protection, local communities and their tremendous properties were saved, and lifelong lessons were learned during the deadliest impacts of Cyclone Nargis 2008. The mangrove ecosystems in Myanmar, however, have been alarmingly threatened due to overexploitation of fuelwood and charcoal production; mangrove conversion to other land uses such as rice fields, shrimp farming, and salt pans; coastal and delta development with human settlement; improper revenue collection on mangrove products in forest management; and climate change and natural disasters. One of the major measures to tackle the existing issues and problems is community-based forest management, called "community forestry (CF)" in mangroves that is a remarkable initiative since 1995 in the aspects of partnership, participation, and decentralization in managing the mangroves in Myanmar. In connection with the findings on the CF study regarding the regeneration of some resilient mangrove species after the impact of Cyclone Nargis, coppice management would be supportive and beneficial to local communities in their own mangrove management. The case study in the chapter demonstrated as well that most of the local stakeholders had fairly sufficient awareness and attitudes to enable

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active participation in mangrove restoration although there were slight differences between the different stakeholders. In particular, poorer attitudes were observed in some migrant communities compared to the settled communities. In developing a mangrove management strategy, inclusiveness should, therefore, be one of the key take-home messages by prioritizing the subsistence needs of the local people plus economic benefits.

Keywords Mangroves · Myanmar · Ecosystem services · Coastal communities · Cyclone Nargis · Awareness and attitude · Inclusiveness

14.1 Physical Attributes and Characteristics

14.1.1 Mangrove Coverage

The World Atlas of Mangroves (Spalding et al. 2010) shows that mangroves cover most parts of Myanmar's coastlines with an estimated area of 502,900 ha, representing 3.3% of the global total and making Myanmar the third largest mangrove coverage in Asia, after Indonesia and Malaysia. In the past, the majority of mangroves occurred in the Ayeyarwady delta, with the remainder in Tanintharyi and a lesser portion in the Rakhine area. Currently, however, mangroves in the Ayeyarwady delta are being depleted at an alarming rate; almost 72% of mangroves in the delta have already disappeared (Table 14.1). With the severe degradation in the mangroves of the Ayeyarwady delta, the mangroves in the Tanintharyi have now turned into the largest areal extent. Similar trends of alarming mangrove degradation and depletion have been shown by the NASA assessment and predictions as shown in Table 14.2. NASA estimated that only 641,486 acres of mangroves will be left in Myanmar by 2030, and the worst condition will fall into the Ayeyarwady delta in which only approximately 32,124 acres of mangroves are estimated.

In Myanmar, the administration of such mangrove forests is with a district-level base. In terms of district forest management, there are 13 districts that represent the existence of mangroves along the coasts, dense or sparse. Considering from the north to the south, for the conservation and management of mangroves together with other

Table 14.1 Mangrove cover change from 1990 to 2015

No.	Region/state	1980 (acres)	2015 (acres)	2020 (acres)	Coverage (%)	Remaining from 1980 to 2020 (%)
1.	Rakhine State	415,137	313,792	302,933	27	73
2.	Ayeyarwady Region	679,540	194,925	192,726	17	28
3.	Tanintharyi Region	647,416	635,266	623,625	56	96
Total		1,742,093	1,143,983	1,119,284	100	64

Sources: FAO (2014, 2020), FD (2019b)

Table 14.2 Mangrove cover assessment in Myanmar

No.	Region/state	Area (acres) 2000	2013	2030
1.	Ayeyarwady Region	202,132	114,163	32,124
2.	Rakhine State	428,481	363,245	170,009
3.	Tanintharyi Region	512,744	504,095	439,353
Total		1,143,357	981,503	641,486

Sources: Weber et al. (2014)

marine resources, Rakhine State is composed of five districts, Ayeyarwady Region three districts, Yangon Region one district, Mon State one district, and Tanintharyi Region three districts. Out of the three districts in the Ayeyarwady Region, Pyapon district manages the largest part of mangroves in the Ayeyarwady delta. These 13 districts have their corresponding management plans to manage forests including mangroves. In the British colonial days, the Ayeyarwady delta was exclusive for the conservation and management of mangrove forests and managed with the Delta Working Plan intended for fulfilling the basic needs of fuelwoods for local communities.

14.1.2 Tides and Their Effects

The tides and their effects are important characteristics in implementing mangrove operations (Hoe 1952). It is a well-known fact that in the Delta, tides rise and fall twice in every 24 h and that each rise or fall occurs about 48 min later each day. The Myanmar calendar which follows the lunar month is useful to indicate the behavior of tides. There are a number of compositions and rhymes in Myanmar illustrating the following certain points:

1. On waxing days, the tide rises at moonset.
2. On waning days, the tide rises at moonrise.

In these two rhymes, the terms moonset and moonrise are used because the setting and the rising can be seen better and cannot be mistaken.

1. On the seventh waning day, the moon rises at midnight.
2. On the 13th day (waxing or waning), the tide rises at sunset or at daybreak.

For fishermen, the latter rhyme is supplemented by catching shrimp and fish at 6 o'clock (with the morning tide). The time at which the tide rises or falls at a place in the delta depends on its distance from the sea and occurs later as the distance increases. At the northern end of deltaic reserves, Table 14.3 gives the approximate times of rises. Tides are very important to mangrove managers and practitioners as well as to every inhabitant, in particular fishermen and the fishery production sector to the delta. Tides largely determine soil formation and hence the rate and kind of

Table 14.3 Tide table according to the dates of Myanmar lunar calendar

No	Day, waxing or waning	Time of rise A.M/P.M		Nature of tides	Myanmar term
		Hour	Minute		
1	First	7	12	High rise	Yehta
2	Second	8	0	High rise	Yehta
3	Third	8	48	High rise, spring tide	Gaungye
4	Fourth	9	36	Almost as high as gaungye	Yesahmi
5	Fifth	10	24	The beginning of the low rises, i.e., medium rise (lower each day)	Yethe-u
6	Sixth	11	12	The beginning of the low rises	Yethu-u
7	Seventh	12	0	The beginning of the low rises	Yethe-u
8	Eighth	12	48	Low rise	Yethe
9	Ninth	1	36	Low rise	Yethe
10	Tenth	2	24	Lowest rises, neap tide	Yesinsin-the
11	Eleventh	3	12	Small rise	Yenuhta
12	Twelfth	4	0	Small rise	Yenuhta
13	Thirteenth	4	48	Small rise	Yenuhta
14	Fourteenth	5	36	The beginning of the low rises, i.e., medium rise (higher each day)	Yehta-u
15	Fifteenth	6	24	The beginning of the low rises, i.e., medium rise (higher each day)	Yehta-u

growth and carry seagrass and mangrove tree seeds to the sea and to accretions which are thereby afforested.

14.2 Ecology and Ecological Processes

With a large share of the Bay of Bengal Large Marine Ecosystem, Myanmar shares common maritime boundaries with Bangladesh, India, and Thailand. The continental shelf covers approximately 230,000 km^2 with a relatively wider portion in the central and southern regions (MFF 2016). The Exclusive Economic Zone (EEZ) is about 486,000 km^2 (BOBLME 2012). Over such a long coastline of over 2800 km from north to south, the Rakhine coast, Ayeyarwady delta, and Tanintharyi coast are the three prominent ecological coastal zones of Myanmar (Fig. 14.1). Mangroves, coral reefs, and seagrass beds flourish mainly in the Myeik Archipelago. Estuaries and mudflats are common in the Ayeyarwady delta, while beach and dunes occur throughout the Myanmar coastline. The diversity of mangroves species found, therefore, are high, and the species distributions and compositions of mangroves differ among the three coastal regions.

Coral reefs and seagrass beds are key ecosystems associated with mangroves. These associated marine ecosystems of Myanmar remain largely unexplored, and the

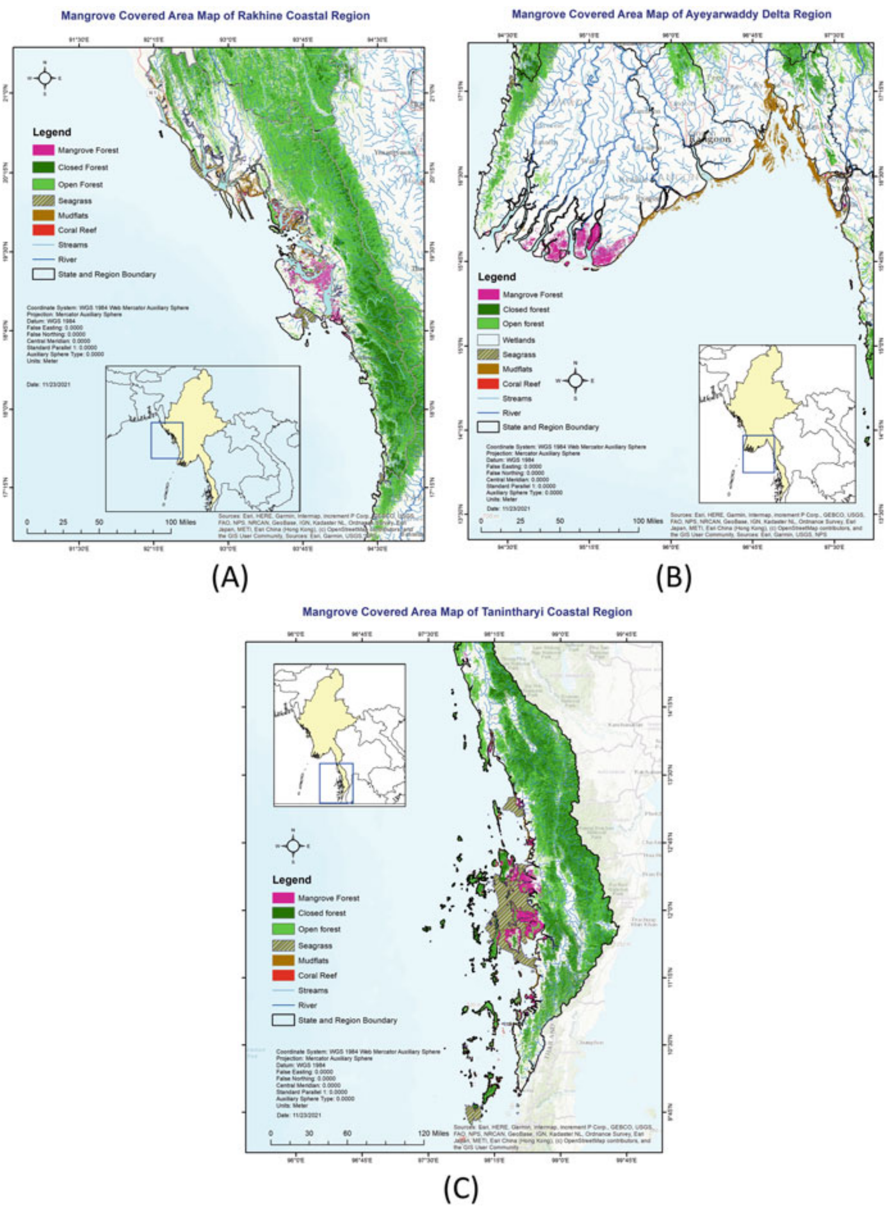

Fig. 14.1 Three main coastlines in Myanmar depicting mangrove area: (**a**) Rakhine coast, upper; (**b**) Ayeyarwady delta, central; and (**c**) Tanintharyi coast, lower

species diversity and health of these two ecosystems are poorly known. An extrapolation of potential habitat area of coral reefs is suggested to be 187,000 ha (BOBLME 2012). Seagrass beds are found in shallow areas interacting with both mangrove and reef communities. There is little information on the status and distribution of seagrass in Myanmar, and the data show that ten seagrass species are currently identified in Myanmar waters (Novak 2009; Tint Tun and Bendell 2010). The health of these key coastal ecosystems largely depends on its nearby mangrove ecosystem and vice versa.

14.3 Floral Biodiversity

The floral patterns of mangroves in the Rakhine coast and the Ayeyarwady delta are very similar to those of the Sundarbans mangrove in Bangladesh and India because of the widespread existence of the genus *Heritiera*. The species diversity in the Myeik Archipelagos of the Tanintharyi coast are more closely related to those in the Ranong region of Thailand. According to the *Mangrove Guidebook for Southeast Asia* by Giesen et al. (2006), there are 148 mangrove plant species in Myanmar; 34 are true mangrove species and the others are shrubs, herbs, and climbers, and associate mangroves. In general, the genus *Rhizophora*, *Sonneratia*, *Avicennia*, *Bruguiera*, *Ceriops*, and *Xylocarpus* spp are dominant in Myanmar (Zöckler and Aung 2019; Nay 2002). The number of mangrove floral biodiversity over all the coasts is not stable as it largely depends on the different sources, and no comprehensive and scientific research has been carried out to cover the whole coastline. The data are produced from quick remote assessment, desk reviews, and the collection of site-specific studies and findings.

In the Ayeyarwady delta, 29 species of mangrove trees are stated, forming the most complicated mangrove system in Asia (Nay 2002). In particular, *Heritiera fomes* is widespread and dominant, and other species that exist this delta include *Excoecaria agallocha*, *Bruguiera gymnorrhiza*, *Cynometra ramiflora*, *Ceriops decandra*, and *Avicennia officinalis* (Ono 2007).

The community patterns of mangrove species after high disturbance by human-induced factors as well as natural disasters have proved to have changed the composition of species (Aung et al. 2013). Long-term observation for 5 years after the impacts of Cyclone Nargis showed that the trends for the mangrove communities of *Avicennia officinalis*, *Bruguiera sexangula*, and *Sonneratia caseolaris* revealed increases in their recovery pathways, while those for *Heritiera fomes* and *Rhizophora apiculata* illustrated decline in their populations. The most prominent finding was that *R. apiculata* communities had disappeared and replaced with *A. officinalis* communities. It is therefore concluded that in case of the same intensity of cyclone like Cyclone Nargis occurs once every decade in the future, *A. officinalis* and *S. caseolaris* species show increasing trends so that they can be supposed to be more persistent and become dominant in the delta compared with other species. Accordingly, they are likely to replace other sensitive communities, in particular

R. apiculata. In terms of wind damage, the sensitivity of species in the Rhizophoraceae and the resilience of those in the Avicenniaceae have also been noted in Australian mangroves that were subjected to cyclones (Woodroffe and Grime 1999). It is also claimed (Smith and Duke 1987) that there are very few Rhizophoraceae in the Sundarbans and that this may be because the adjacent Bay of Bengal receives 30–40 typhoons a year.

Similar to the dominance of specific mangrove species communities after wind-induced disturbance, the most common species grown for plantations since mangrove rehabilitation started in 1982 by the Forest Department (FD) are *Avicennia officinalis*, *A. marina*, *Sonneratia caseolaris*, and *Bruguiera* species. In current mangrove rehabilitation projects, the two most common species planted are *A. officinalis* and *S. caseolaris* as these are fast growing and provide protection against cyclones and natural disasters with the quick returns of coastal protection services.

The mangrove species and communities are therefore observed being unstable in the Ayeyarwady delta due to the compounded effect of natural and human-induced disturbance. Regardless of the community shift and species disappearance, the 40 true mangrove species with their conservation status in Myanmar are listed in Table 14.4 (Giesen et al. 2006; Aung 2016; Yong 2016), but more comprehensive study and scientific research are needed.

San (2020) stated that among all three main mangrove tracts in Myanmar, the coastal study site of the Tanintharyi coast showed the highest species diversity of mangrove vegetation while the least species diversity was observed at the coastal site of the central region where the ground level was higher and species zonation was mostly dominated by the high intertidal species community. Roth et al. (1994) also noted that the greater the disturbance, the lower the species richness and evenness, with the increasing dominance of fewer species. The indices for the species diversity and evenness of the studies over all three coastlines in Myanmar are shown in Table 14.5.

14.4 Faunal Biodiversity

The mangroves in Myanmar are supporting a wide range of vertebrate and invertebrate species, including several globally threatened mammal and bird species. For example, the fishing cat *Prionailurus viverrinus* (EN) (Fig. 14.2) and smooth-coated otters *Lutrogale perspicillata* (VU) have been regularly observed in the Tanintharyi Region (Zöckler and Aung 2019). Furthermore, the Asian wild dog called dhole *Cuon alpinus* (VU) has been recorded in the delta region (Zöckler and Kottelat 2017). Quite prominent and possibly unique for Myanmar and its coastal habitats is the good number of Irrawaddy dolphins *Orcaella brevirostris* frequently entering the mangrove channels and coasts near the mangroves in all three mangrove regions (Zöckler and Aung 2019). The globally near-threatened (NT) Indo-Pacific humpbacked dolphin, *Sousa chinensis*, is still present in good numbers (Moses and

Table 14.4 True mangrove species and their conservation status in Myanmar

No.	Species name	Family	Ayeyarwady delta	Rakhine/western coastline	Tanintharyi/southern coastline	Conservation status
1.	*Acanthus ebracteatus*	Acanthaceae	☑	☑	☑	LC
2.	*Acanthus ilicifolius*	Acanthaceae	☑	☑	☑	LC
3.	*Acanthus volubilis*	Acanthaceae	☑	☑	☑	LC
4.	*Acrostichum aureum*	Pteridaceae	☑	☑	☑	LC
5.	*Acrostichum speciosum*	Pteridaceae	☑	☑	☑	LC
6.	*Aegialitis rotundifolia*	Myrsinaceae	☑	☑	☑	LC
7.	*Aegiceras corniculatum*	Plumbaginaceae	☑	☑	☑	NT
8.	*Aglaia cucullata*	Meliaceae	☑	–	–	DD
9.	*Avicennia alba*	Avicenniaceae	☑	☑	☑	LC
10.	*Avicennia marina*	Avicenniaceae	☑	☑	☑	LC
11.	*Avicennia officinalis*	Avicenniaceae	☑	☑	☑	LC
12.	*Brownlowia tersa*	Tiliaceae	☑	–	☑	LC
13.	*Bruguiera cylindrica*	Rhizophoraceae	☑	☑	☑	LC
14.	*Bruguiera gymnorrhiza*	Rhizophoraceae	☑	☑	☑	LC
15.	*Bruguiera hainesii*	Rhizophoraceae	☑	☑	☑	CR
16.	*Bruguiera parviflora*	Rhizophoraceae	☑	☑	☑	LC
17.	*Bruguiera sexangula*	Rhizophoraceae	☑	☑	☑	DD
18.	*Ceriops decandra*	Rhizophoraceae	☑	☑	☑	NT
19.	*Ceriops tagal*	Rhizophoraceae	☑	☑	☑	LC
20.	*Cynometra iripa*	Fabaceae	☑	☑	☑	LC
21.	*Dolichandrone spathacea*	Bignoniaceae	☑	☑	☑	LC
22.	*Excoecaria agallocha*	Euphorbiaceae	☑	☑	☑	LC
23.	*Heritiera fomes*	Sterculiaceae	☑	☑	☑	NT
24.	*Heritiera littoralis*	Sterculiaceae	☑	☑	☑	LC
25.	*Kandelia candel*	Rhizophoraceae	☑	☑	☑	LC

26.	*Lumnitzera littorea*	Combretaceae	☑	☑	☑	LC
27.	*Lumnitzera racemosa*	Combretaceae	☑	☑	☑	LC
28.	*Nypa fruticans*	Arecaceae	☑	☑	☑	LC
29.	*Phoenix paludosa*	Arecaceae	☑	☑	☑	NT
30.	*Pemphis acidula*	Lythraceae	N/A	N/A	☑	LC
31.	*Rhizophora apiculata*	Rhizophoraceae	☑	☑	☑	LC
32.	*Rhizophora mucronata*	Rhizophoraceae	☑	☑	☑	LC
33.	*Scyphiphora hydrophyllacea*	Rubiaceae	☑	☑	☑	LC
34.	*Sonneratia alba*	Sonneratiaceae	☑	☑	☑	LC
35.	*Sonneratia apetala*	Sonneratiaceae	☑	☑	☑	LC
36.	*Sonneratia caseolaris*	Sonneratiaceae	☑	☑	☑	LC
37.	*Sonneratia* hybrid	Sonneratiaceae	☑	–	☑	EN
38.	*Sonneratia griffithii*	Sonneratiaceae	☑	☑	☑	CR
39.	*Xylocarpus granatum*	Meliaceae	☑	☑	☑	LC
40.	*Xylocarpus moluccensis*	Meliaceae	☑	☑	☑	LC

LC least concern, *DD* data deficient, *NT* near-threatened, *VU* vulnerable, *EN* endangered, *CR* critically endangered
(☑) present, (N/A) absent, and (–) data deficient
Note: Modified from Giesen et al. (2006), Aung (2016), and Yong (2016)

Table 14.5 The species diversity indices of the study sites at different coastal regions in Myanmar (tree species ≥5 cm in dbh) by San (2020)

Mangrove region	Study site	Number of species	Diversity indices		
			Simpson (D′)	Shannon–Wiener (H′)	Evenness (E)
Rakhine (upper)	Coastal	14	0.79	1.83	0.69
Rakhine (upper)	Island	12	0.67	1.37	0.55
Ayeyarwady (central)	Coastal	16	0.51	1.18	0.43
Ayeyarwady (central)	Island	8	0.81	1.75	0.84
Tanintharyi (lower)	Coastal	12	0.83	1.93	0.78
Tanintharyi (lower)	Island	16	0.81	1.97	0.71

Fig. 14.2 Wild cat in the mangroves of Ayeyarwady delta (Photo: Hkun Lat)

Zöckler 2016). A total of over 230 species of birds were observed in Myanmar's mangroves (Zöckler and Aung 2019). The lesser adjutant stork *Leptoptilos javanicus* (VU), mangrove pitta *Pitta megarhyncha* (NT), and brown-winged kingfisher *Pelargopsis amauroptera* (NT) are characteristic flagship species and still present in good numbers in the southern mangroves in Tanintharyi but scarce in the delta area and largely missing in the Rakhine region. Mangroves and associated mudflats are also home to a number of migratory water birds. A total of more than 20,000 migratory water birds have been counted regularly in winter in the southern Tanintharyi mangroves and mudflats alone, and among these are several globally threatened water birds (Zöckler and Aung 2019). Among the reptiles such as snakes, crocodiles, and lizards, the most prominent examples are the estuarine crocodile

Crocodylus porosus and the mangrove monitor lizard *Varanus indicus* (Thorbjarnarson et al. 2000). Several species of marine and freshwater turtles live exclusively in the mangroves, for example, the mangrove terrapin *Batagur baska*, but this has no longer been observed in Myanmar's mangroves since the early 2000 (Platt et al. 2008).

There are limited comprehensive studies and observations of faunal diversity all over the Myanmar's mangroves. Just after the independence of Myanmar from the British colony, in the Ayeyarwady Delta Working Plan (1948–1957), the following compressive and detailed wildlife information were recorded.

Elephants There were two herds of elephants, among which some were tuskers. The elephants in the mangroves were smaller than those generally found in Myanmar and migrate to northern reserves in the hot season for freshwater and fodder. Their favorite foods were cane, *thinbaung*, *danon*, *thaing*, and *kyu*. No case of destruction of crops was reported. No shooting or catching licenses were issued. A few elephants inhabited the mangrove areas near Shwe Thaung Yan Beach in the delta, and they were said to come down from the nearby terrestrial forest range.

Monkeys There were three kinds of monkeys; myauktanga is a small type living near banks and catching fish and otters. The brown medium-sized monkey is myauknyo, living on the tree tops and eating tender shoots of danon, thinbaung, etc. Myaukmido is tailless, frequenting only deep jungle and eating fruits and shoots.

Sambhur, Barking and Hog Deer, and Wild Pig These were found in all reserves. In the cold weather of 1945, there was an epidemic among wild pigs, and several carcasses were found in Labyauk reserve.

Tiger These were no longer found but they were reported in Kamahuak, Pathi, Anuak Htawbaing, Yakhing aw, and Myauk taya areas in the working plan 1947–1948 to 1956–1957.

Crocodiles They were fairly common and found in quiet places. The biggest measured some 14 feet in length. The Meinmahla Kyun Wildlife Sanctuary (MKWS) is intended for crocodile protection.

Others Hornbill, snipe, parrot, golden, plover, kingfisher, green pigeon, woodpecker, wild fowl, teal, wild cat, and rabbit are found in all reserves, whistling teal breeds in the delta. Spoon-billed sandpipers are also still found in Meinmahla Wildlife Sanctuary.

Site-specific faunal biodiversity can be observed in two exclusive mangrove parks, Meinmahla Kyun Wildlife Sanctuary (MKWS) and Lampi Marine National Park (LMNP).

According to the park management plan of MKWS, there exist 15 mammals including Ayeyarwady dolphin, monkey, and otter; 38 amphibians and reptiles including estuarine crocodiles and Burmese python, 186 bird species, 110 fish species, and 35 butterfly species have been recorded. The park supports globally threatened species such as the critically endangered hawksbill turtle (*Eretmochelys* *imbricata*) and mangrove terrapin (*Batagur baska*). Other threatened species include the endangered great knot (*Calidris tenuirostris*), Nordmann's greenshank (*Tringa guttifer*), green turtle (*Chelonia mydas*), and dhole (*Cuon alpinus*). Vulnerable species include the Pacific ridley turtle (*Lepidochelys olivacea*), fishing cat (*Prionailurus viverrinus*), lesser adjutant (*Leptoptilos javanicus*), and Irrawaddy dolphin (*Orcaella brevirostris*). It is also the last estuarine habitat in Myanmar for the saltwater crocodile (*Crocodylus porosus*).

The Lampi Marine National Park (LMNP) is the only marine national park in Myanmar. LMNP is located in the Myeik Archipelago. It is well known for its rich biodiversity and pristine and untouched mangrove habitats. Its management plan describes including 228 bird species, 19 of which are listed as threatened in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, including the plain-pouched hornbill and the Wallace hawk eagle, 10 amphibians and 19 reptile species, 3 species of sea turtles (the green sea turtle, the loggerhead sea turtle, and the olive ridley sea turtle), and 19 species of small, medium, and large mammals, 7 of which are in danger according to IUCN, including the Sunda pangolin and the dugong.

14.5 Ecosystem Services of Mangroves in Myanmar

Mangroves in Myanmar are predominantly found in the estuaries, deltas, lagoons, and coastal shorelines of all three main coastal regions. A total of ten provisioning, regulating, supporting, and cultural services were considered (Estoque et al. 2018), focusing on those that were believed to be of the greatest importance in economic and human well-being terms and drawing on the categorization of marine and coastal realm habitats and ecosystem services suggested in the Millennium Ecosystem Assessment (UNEP 2006). These ecosystem services accounted for are wood-based energy and timber, other sources of foods, fibers, medicines, coastal protection, hazard mitigation, regulation of water flow, regulation of water quality, mitigation of climate change, maintenance of fishery nursery populations and habitat, and recreation and experiential, cultural, amenity, and aesthetics. The goods and services are identified and evaluated as follows (Table 14.6).

Out of the ten ecosystem services provided by mangroves, the maintenance of fishery nursery and habitat has the highest value followed by coastal protection. The majority of the population on the coasts live with fisheries. In changing patterns of global climate and increasing vulnerability to tropical cyclones, the function of coastal protection to the lives and property of coastal communities is becoming a

Table 14.6 Values of mangrove ecosystem services of Myanmar modified from Emerton and Aung et al. (2013) and Estoque et al. (2018)

Ecosystem services	Components of ecosystem services in Myanmar	Ecosystem service value (ESV) (2018 USD)/ha/year
1. Wood-based energy and timber	Due to limited electricity access to the Ayeyarwady delta and remote coastal islands over Myanmar's coasts, local communities rely mainly on firewood and charcoal as fuel energy for their daily household consumption for cooking meals. Wood, posts, and poles for construction of local houses are also used from mangrove products. In addition, mangrove poles and posts can be utilized as fishing tools and fishing nets. Mangrove timber products are used widely around all three coastal tracts of Myanmar for subsistence though the availability of mangrove timbers is limited in quality and quantity	7.22
2. Other sources of foods, fibers, medicines, etc.	Non-timber forest products for food, fibers, medicine, etc. which are available directly or indirectly are provided from mangrove ecosystems. In the kitchens of local communities, they are always full of fishery products: fish, prawn, shrimp, crab, clams, mussels, etc. Local communities can extract the leaves of mangroves as foods. For instance, the leaves of *Acrostichum* species provide vegetables to make toast with fish pastes in everyday meals. Honey production from mangroves is also marketable. In addition, collection of barks from the woods of mangroves can be utilized as dyes. Nypa's leaves are used for roofing and walling. The shoots and fresh leaves from Nypa have become commercially and widely produced and exported for the production of medicines and cigars	2.89
3. Coastal protection	In degraded mangrove areas, riverbank and coastal erosion seriously occur while they are well protected in the protected areas of mangroves. The entangled aboveground root systems in mangrove communities, in particular, *Rhizophora* and *Avicennia* communities, protect coastlines during storm events as they can absorb wave energy and reduce the velocity of waves. Many species of mangroves also have extensive cable root systems which assist in binding sediment particles. The riverbanks and coastlines covered with mangrove	1369.28

(continued)

Table 14.6 (continued)

Ecosystem services	Components of ecosystem services in Myanmar	Ecosystem service value (ESV) (2018 USD)/ha/year
	communities are less likely to erode than unvegetated shorelines during periods of high wave energy	
4. Hazard mitigation	Myanmar is a cyclone-prone country. The western coasts and the Ayeyarwady delta suffer from tropical cyclones every year. The intensity of tropical cyclones has become more and more intense (change to "severe"), and the mangrove greenbelts can largely reduce its intensity. The shorelines covered with mangrove vegetation acted as an effective windbreak during the cyclone events, protecting leeward coastal settlements from intense storm damage, especially during the deadliest Cyclone Nargis 2008. Storm surge caused by Cyclone Nargis which hit the Ayeyarwady delta in early May 2008 caused about 140,000 casualties of death and damage to the economic sectors of coastal communities. During the impact of the cyclone, the "Meinmahla Kyun Wildlife Sanctuary" fully covered with mangrove vegetation saved thousands of local communities. Since the severe impact of the cyclone to the local communities, policy makers recognized the critical role of mangroves in protecting from the tsunami and cyclones and prioritized mangrove conservation and rehabilitation. Considerable mangrove afforestation is being done so as to minimize the damage to delta and coastal villages and agricultural land from the frequent and intense cyclones	349.01
5. Regulation of water flow	The prop roots of *Rhizophora apiculata* and the pencil-like roots of *Avicennia* species trap sediments and waste. In addition, flocculated clays are largely deposited within the mangrove zones of estuaries; many nutrients which are adsorbed onto the clay particles are also retained within the mangrove systems. This function of mangrove systems not only prevents the loss of nutrients from the catchment area to the sea but also removes the polluted wastes from the water column and stores them in the mangrove sediment. Plastic pollution is one of the major issues in the coastal regions of	275.27

(continued)

Table 14.6 (continued)

Ecosystem services	Components of ecosystem services in Myanmar	Ecosystem service value (ESV) (2018 USD)/ha/year
	Myanmar, and it blocks the river and stream flows in the mangroves in the proximity of urban areas	
6. Regulation of water quality	With their own local knowledge, the farmers in the Ayeyarwady delta traditionally prevent saltwater intrusion to their paddy fields by planting and maintaining mangroves along the rivers and stream banks close to their farms. Mangroves therefore provide two actions: the function of windbreak to absorb wind energy of tropical cyclones and the functions of mangrove roots and vegetation can also reduce the erosive tendency of water, enhance the formation of clay deposits, minimize the subsequent resuspension of these clay deposits, and trap the sediment particles and heavy metal deposits. In such ways, the quality of water in mangroves is improved. This sort of mangrove service helps when excess sediment is generated by human activities such as road construction, deforestation, mining, and large-scale concession of long-term cash crops	617.13
7. Mitigation of climate change	Mangroves are known to act as carbon sinks and have sequestration functions comparable with other ecosystems. Taking this opportunity, conservation and management of mangroves have been viewed as mitigation and adaptation of climate change. Nowadays, international organizations like WIF—Worldview International Foundation—have been implementing voluntary carbon standards (VCS) in progress for global climate change mitigation programs. Such a carbon mitigation program is associated with the livelihood improvement for local people. UNDP and FAO also started implementing mangrove projects associated with REDD+ and climate change adaptation while improving the livelihoods of local communities	304.64
8. Maintenance of fishery nursery populations and habitat	Globally marketable fisheries, in particular tiger prawns and mangrove mud crabs, are highly commercial. These fishery products are exported to China, Thailand, Japan, Singapore, and Europe. The basic needs	9122.45

(continued)

Table 14.6 (continued)

Ecosystem services	Components of ecosystem services in Myanmar	Ecosystem service value (ESV) (2018 USD)/ha/year
	and foods for mangrove-dwelling communities are fairly covered by these fishery products. Local communities are therefore highly aware of their traditional knowledge to maintain mangrove areas as the nurseries and habitats of fish, shrimps, crabs, etc. Most importantly, the food security for the communities and residents over the delta and coasts is largely covered by the fishery products from mangrove ecosystem services	
9. Recreation and experiential	Nature-based ecotourism has become one of the tourist attractions in the "Meinmahla Kyun Wildlife Sanctuary" in the Ayeyarwady delta to learn about crocodile nests and juveniles and do research on mangrove biodiversity as well as for educational purposes. The only marine national park with pristine mangroves "Lampi Marine National Park" is also another attraction of wilderness. Such mangrove estuaries provide food for the wildlife which inhabit the marine ecosystems and are the habitat of many wildlife species including water birds, crocodiles, tiger, wild elephants, monkeys, deer, and bees. Thus, mangroves and wetlands are "the so-called natural supermarket" for local communities because they support the coastal communities' food chain and rich biodiversity. Many countries earn income from ecotourism in the mangrove ecosystem. Rich biodiversity also attracts researchers to carry out more research activities in this pristine ecosystem. Unexpectedly, the current situation in Myanmar with "3C" by the political conflict, the pandemic of covid-19, and the civil war widespread has become a dilemma in developing this ecotourism sector, and its values is an estimated downward trend	475.97
10. Cultural, amenity, and aesthetics	Mangrove seascapes are significant to human well-beings for the relief of stresses and mental and physical health of people. Its associated ecosystems of coral reefs and seagrass also support its ecosystem services and values	28.46

key component in coastal regions of Myanmar. These ecosystem services, however, are not well recognized and undervalued by decision-makers. Awareness should be raised within decision-making processes in solving resource use and land-use conflicts.

14.6 Regeneration of Mangrove and Silviculture

The natural regeneration status of mangroves is largely influenced by the availability of seeds and propagules, existence of mother trees nearby, normal hydrology, tide and waves, and soil. The viviparous seedlings are already germinated while they are still attached to the mother plants and still receive nutrients from the mother tree (Panneerselvam 2008). According to the comprehensive study for all three main coastal regions in Myanmar (San 2020), it revealed that the occurrence of seedlings and saplings of the important species was inadequate in all study sites except the coastal study site of the lower coastal region, Myeik archipelagos. For all study sites, the number of species counted as natural regeneration was lower than that of the number of species recorded as trees with dbh ≥5 cm. The coastal study site of the central coastal region, the Ayeyarwady delta, was observed to have the poorest natural regeneration status, where the number of regenerated species represented only 50% of the recorded tree species. This could be the result of a smaller number of seed trees per hectare, extensive encroachment of weeds that outcompete seedlings in the initial stage of establishment, and a lack of tending operations after the Cyclone Nargis. Kairo et al. (2001) noted that the lack of mother trees leads to lower supply of propagules. It clearly indicates the requirement of silvicultural measures to create favorable conditions for seedling establishment in all mangrove regions over the coasts of Myanmar (Fig. 14.3).

14.6.1 Post-Cyclone Mangrove Regeneration and Reproduction

Myanmar is a cyclone-prone country, and the number of cyclones becomes frequent and intense not only in the Ayeyarwady delta but also along the whole coastal line, including the western Rakhine coast. The mechanisms of cyclone damage are related to a variety of factors, such as wind fields, wave energy, water levels, sediment dynamics, and chenier formation, all of which may affect the characteristics of mangrove sensitivity to a greater or lesser extent (Paling 2008; Cahoon and Hensel 2002). Accordingly, the wind-induced damage was observed as a key driver in changing patterns of post-cyclone mangrove regeneration and reproduction. In terms of wind damage, the sensitivity of the Rhizophoraceae and the resilience of

Fig. 14.3 Epicormic sprouts of *Heritiera fomes*, two and half years later after Cyclone Nargis (Photo: Toe Aung)

the Avicenniaceae have also been noted in Australian mangroves that were subjected to cyclones (Woodroffe and Grime 1999; Smith and Duke 1987). There are also very few Rhizophoraceae in the Sundarbans, and this may be because the adjacent Bay of Bengal receives 30–40 typhoons a year. A study on the cyclone-affected mangroves reaffirmed that *A. officinalis* has shown its greatest ability for vegetative reproduction whereas most Rhizophoraceae species had no vegetative reproduction (Aung et al. 2013). A study on epicormic sprouts on stumps from human impacts (Ono and Fujiwara 2004) also states that *A. officinalis* had more sprouts than did other species. According to Tomlinson (1986), mangrove Rhizophoraceae are distinctive because they lose the ability early to produce reserve meristems, whereas most other common genera (e.g., *Avicennia*, *Laguncularia*, and *Sonneratia*) retain reserve meristems and develop epicormic sprouts when damaged. It also seems probable that pioneer mangrove species, high light demanders, have the ability to produce abundant sprouts after natural disturbance. Aside from most Rhizophoraceae, most other species were also observed to have a considerable ability to produce vegetative shoots, although sprouting ability was not as high as in *A. officinalis*.

The measures to conserve, restore, and manage mangroves after cyclone disturbance, therefore, require understanding the regeneration and reproduction patterns.

Aung et al. (2013) showed that two communities of *B. sexangula* and *R. apiculata* shifted to *Avicennia officinalis* community, considerably farther from their pre-cyclone origins in ordinated space, compared to the others. Baldwin et al. (2001) indicates that moderately damaged mangroves were leading to single species stands, and severely damaged ones led to mixed species stands. Rashid et al. (2009) also report on the invasion of non-mangrove species after catastrophic disturbance. The years following the impact of a cyclone are challenging for mangrove species, as they compete with a number of herbaceous invaders and other opportunists. Therefore, species that are fast growing and demand a lot of light appear to have higher potential for competing successfully with invader species. The mangrove regeneration after the storm disturbance relying primarily on seedling recruitments has also been noted (Smith et al. 1994; Cahoon and Hensel 2002).

Mangroves, therefore, affirm their resiliency with high potential regeneration. With respect to the reason for recovery delay, Milbrandt (2006) states that delays in forest recovery are possible in severely impacted areas if either the delivery of propagules or the production of seedlings is reduced by habitat fragmentation. Most of the catastrophic disturbances have occurred neither by massive die-offs nor by parasitic infections; the real chronic ecological degradation has been proven when humans mismanage the systems and allow irreversible environmental changes from which recovery is almost impossible. It can be concluded in the post-cyclone mangrove regeneration, then, that mangroves can recover from catastrophic cyclone impact within a short period of time, with the exception of the *Rhizophora* genus, found to have been affected by intense winds (Aung et al. 2013).

14.6.2 Silvicultural Implication After the Cyclone Disturbance

Experience from coppicing true mangrove species will be used for depleted mangrove forests, especially in mangrove community forestry in the Ayeyarwady delta. The higher regeneration capacity with sprouting and coppicing should be tested as plantation models for beginning coppicing operations in mangrove community forestry programs that support the quick production for firewood demand. For example, *A. officinalis*, *H. fomes*, *S. caseolaris*, and *E. agallocha* have good potential for coppice management practices in community-based projects; *H. fomes* is also appropriate for coppice management (Aung et al. 2009; Ono and Fujiwara 2004). However, some of the Rhizophoraceae species should not be recommended for coppicing management operations. Whether or not silvicultural intervention is needed for post-cyclone mangroves is important for both foresters and ecologists. Following such disturbances, the persistence of non-mangrove species, mangrove-associated species, and invasive species, rather than true mangroves species, is easy to invade in large gaps and so could lead to critical ecological degradation and biological invasion. Most of the mangrove species have such patterns of release and

Table 14.7 5R—recovery index—based on four factors (Everham and Brokaw 1996) and one added factor with environmental risk (Aung 2012)

Community	Recovery factors			Risk factors		Recovery index	
	Recruitment	Release	Resprouting	Repression	Retreat		
A. officinalis	5	4	5	3	1	3.50	+++++
B. sexangula	5	3	0	5	0	1.60	++
E. agallocha	0	1	3	4	0	1.00	+
H. fomes	0	3	4	3	0	2.33	++
R. apiclata	0	1	0	3	3	0.17	-
S. caseolaris	1	1	4	1	2	2.00	++

Note: 0 for no recovery, and the higher the values, the more rapid the recovery of each community

wait for the canopies to open, after they incur certain kinds of crown damage either from natural disturbances, self-thinning, or proper harvesting. In addition, Imai et al. (2006) state that having many large gaps may help seedlings and saplings of *Sonneratia alba* and *Avicennia alba*, which need sunny conditions for their growth.

Aung et al. (2013) showed that the species-specific levels show different recovery pathways, although mangroves are generally highly resilient. *B. sexangula* and *R. apiculata*, which belong to the Rhizophoraceae group, were found to be more sensitive to natural disturbance, presumably wind-induced impact, while the other species showed more resilience. In the *Rhizophora*-dominated community, it is the indirect rather than the direct consequences of cyclones that slow the recovery process of these species-dominated sites. Management intervention in the cyclone-sensitive communities might be necessary in order to mitigate the adverse effects of catastrophic disturbances such as erosion and invasion by herbaceous species. To summarize, most mangrove species rely strategically on natural recovery processes and patterns, but for conservation purposes, attention should be paid to some sensitive communities suffering indirect, negative consequences following cyclones (Table 14.7).

Unlike other terrestrial forest species, mangroves are rarely treated with intensive silviculture operations. It might be due to the purposes of fuelwood production, reserve forests in the past, and windbreak and biodiversity conservation as the current trend. Most of the silvicultural operations are aimed to raise the regeneration such as regeneration improvement felling (RIF), pruning, coppice management, thinning, canal clearance, hydrological modification, gap planting, and weeding. In order to produce firewood and domestic use of poles and posts, the most common silviculture operations used by the mangrove community forestry areas are RIF and pruning. Taking advantage of the high capacity of mangrove species in regeneration and vegetative reproduction such as *Heritiera fomes* and *Avicennia officinalis* that produce quality wood and charcoal, coppice management is recommended to be widely practiced both for the protected public forests and community forests.

14.7 Global Climate Change and Mangroves

Observed changes in the climate for Southeast Asia include increasing temperature, variable precipitation, sea level rise, and an increase in the frequency and magnitude of extreme weather events (MONREC 2019). It has been revealed that Myanmar's climate is changing with certain observable trends over the last six decades (Hijioka et al. 2014). It shows an increase in mean temperature (~0.08 °C per decade), increase in overall rainfall (varying between 29 and 215 mm per decade throughout the country) with a declining trend in some areas, late-onset and early termination of southwest monsoon, increase in extreme weather events, and sea level rise. A closer look at observed data reveals that intense rainfall events are experienced with shorter monsoon period, and extreme events like destructive cyclones make landfall over Myanmar coastline every year as compared to typically once in three years during the twentieth century. Some key observed extreme events are presented below:

- An increase in the intensity and frequency of cyclones and strong winds: From 1887 to 2005, 1248 tropical storms formed in the Bay of Bengal. Eighty of these storms (6.4 % of the total) reached Myanmar's coastline. Cyclones Mala (2006), Nargis (2008), and Giri (2010) were the most severe and damaging cyclones experienced in Myanmar.
- Rainfall variability including erratic and record-breaking intense rainfall events: Every year Myanmar experiences intense rainfall. From July to October in 2011, there was heavy rain and flooding in the Ayeyarwady, Bago, Mon, and Rakhine regions.

Projected climate changes include the following:

- An increase in the occurrence and intensity of extreme weather events includes cyclones/strong winds, flood/storm surge, intense rains, extreme high temperatures, drought, and sea level rise.
- Table 14.8 presents the initial results of climate change projections based on the PRECIS model.

14.7.1 Cyclone Nargis

The changing condition of frequent and intense storms exacerbated by climate change scenarios would affect the coastal population in Myanmar more severely. Cyclone Nargis in May 2008 was the worst natural disaster in the history of Myanmar and the most devastating cyclone to strike Asia since 1991 (TCG 2008). It was also the tenth deadliest cyclone in the world on record (www.wunderground.com) and had significant effects on 37 townships in which most of them are mangrove areas in the Ayeyarwady delta and Yangon Coast. The effects of cyclonic winds were compounded by a 3–4-m storm surge and left almost 140,000 people dead and missing in the delta (TCG 2008). Mangroves are the only high-structure

Table 14.8 Climate change projection in coastlines where mangroves are common

Climate change predictions for 2001–2020 include	Climate change predictions for 2021–2050 include	Climate change predictions for 2051–2100 include
• An increase in temperature of ~ 0.4 °C–0.7 °C across Myanmar with the Ayeyarwady deltaic region experiencing the greatest increase (~0.7 °C) • Highly variable rainfall changes throughout the country including large increases (~228 mm in annual average volume) in the northern Hilly region as well as decreases (~58 mm annual average volume) in the Rakhine coastal, Yangon deltaic, and southern Tanintharyi coastal regions	• An increase in temperature of 0.8 °C–1.4 °C across Myanmar with the Yangon deltaic (1.4 °C) and Rakhine coastal regions (1.2 °C) experiencing the greatest increase • An increase in rainfall across the country with the Rakhine coastal region experiencing the greatest increases (~661 mm in annual average volume) and the eastern Hilly region experiencing the smallest increases (36 mm/annum)	• An increase in temperature of 2.8 °C–3.5 °C across Myanmar with the highest increases in the Rakhine coastal and Yangon deltaic regions (3.5 °C) • An increase in precipitation with highest increases (~1582 mm in annual average volume) in the Rakhine coastal and smallest increases in the eastern Hilly region (~209 mm in annual average volume)

vegetation thriving across the tropical coastline and in this context largely reduced the intensity of storms. Since the tragic lessons learnt from such deadly cyclone on the Ayeyarwady delta, Myanmar is now trying to protect its coastline with greenbelts. The protected public mangrove forests are increasingly being established. For instance, Yangon Region where there were no protected mangroves before now has its coastline protected with newly accrued mangroves by constructing natural infrastructure and greenbelts.

Mangroves in the newly accrued land are well planned to conserve for the protection of vulnerable coasts along the Mottama Gulf in Yangon Region.

14.8 Livelihoods

The majority of the coastal communities depend upon fisheries and agriculture, with the minority living on tourism and industrial development. The major livelihoods in the mangrove areas of Ayeyarwady delta can be categorized into (a) agricultural people, (b) fishery people, and (c) casual labor people (JICA 2005). Farmers are also used to domesticating buffalo, duck, chicken, and fish. A number of coastal communities suffer from poverty and a lack of viable livelihood options (Han 2010).

14.8.1 Fisheries

Mangrove areas fall in inshore fishery zones that are within five nautical miles from the shore along the Rakhine coast and ten nautical miles from the shore for the

Ayeyarwady and Tanintharyi coasts (MFF 2016). Fisheries, in particular artisanal fisheries, are the major livelihoods for local communities in mangrove areas. Fishery people in the mangrove areas can be seen as two types: full-time and part-time fishery people. Full-time fishery people earned much more than the high-income farm groups, while part-time fishery households (landless households) engaged in crab catching on a subsistence basis. The majority of small farmers and landless households also work as agricultural laborers during the peak agricultural season as the average daily wage rate increases.

The mangrove areas in other coastal areas have similar livelihoods to the Ayeyarwady delta. In Rakhine, poverty is the highest incidence in Myanmar. According to a World Bank analysis in 2014, the poverty in Rakhine is 78% compared to a national average of 37.5%. Due to low levels of land ownership and income in the state, 63% of the population depends on casual labor as a source of income, with agriculture followed by fisheries being the main sectors employing casual laborers. An assessment by REACH (2015) in the coastal districts of Maungdaw, Sittwe, Pauktaw, Minbya, and Myebon in northern Rakhine found that 85–88% of households live in storm-vulnerable housing constructed with only thatched roofs.

In the Myeik Archipelagos of the Tanintharyi coast, the Moken, also called sea gypsies or Salone in Burmese language, who live their traditional nomadic lifestyles are solely dependent on fishing and harvesting of sea cucumbers. It is estimated there are approximately 1000 indigenous Moken in the Myeik Archipelago and adjacent areas of the Andaman Sea.

14.8.2 Mangrove Aquaculture Ponds

Production of marine fish through aquaculture is relatively small compared with production of shrimp from aquaculture in mangrove areas or production of wild caught marine fish (FAO 2003). Aquaculture is practiced largely in brackish water along the mangrove areas close to the sea and coastline. One of the highest incomes is derived from the livelihood of mangrove aquaculture ponds, which is largely extensive with limited semi-intensive ponds. Typically, farmers build low earthen walls around their mangrove area. To increase productivity, many farmers also put additional shrimp fingerlings and juvenile crabs into the ponds (GGKP 2020). Basically, the farmers do not feed the fish in the ponds; the crabs, shrimp, and fish depend on natural food that is carried in by river water and from adjacent mangroves. In the current typical mangrove aquaculture system, farmers use polyculture systems that include crab, shrimp, and other fish cultured together. Tiger prawns, orange-spotted groupers, greasy groupers, and soft-shelled crabs are cultured in pond farms in the mangrove areas.

In many areas, mangroves have been converted to aquaculture ponds, for instance, in the reserved mangrove forest of Wunbaik, Rakhine, a total of 1176 ha of mangroves has been converted to shrimp ponds since the 1980s (Stanley et al.

2011). As a result, there is a need to develop environmentally friendly aquaculture, sustainable aquaculture, as well as conservation measures for mangrove resources. Now, without cutting mangrove vegetation, mangrove-friendly crab fattening is being driven as one of the community support livelihoods by introducing to the community forest based enterprises (FD 2019a).

14.8.3 Mud Crab Catching

A significant number of landless farmers in mangroves depend on catching crabs in the mangrove areas, which is an important activity in coastal rural areas along the Myanmar coast. It is common for the landless people as their major livelihood.

14.8.4 Rice Cultivation

The mangrove areas have been converted to rice agriculture. A large part of the Ayeyarwady delta is submerged by brackish water. In the rainy season, the middle and upper parts of the Ayeyarwady delta are covered with water of zero salinity, almost freshwater. Rice cultivation, therefore, is a major livelihood in the Ayeyarwady mangroves. It is reported that 98% of mangrove deforestation (Giri et al. 2008) was cleared and converted to other land uses for agriculture, in particular rice fields. Richards and Friess (2015) stated that 87.6% of the Ayeyarwady mangroves have been converted to paddy cultivation. The different types of rice cultivation in mangrove areas are found in Rakhine State, in which the rice cultivation and shrimp farming are alternatively carried out season by season. It is locally called "Kari." In the rainy season, farmers use their lands as rice fields and then in other open seasons, as shrimp ponds. However, such rice cultivation and extensive shrimp farming culture are rarely found in the mangrove areas of Tanintharyi as local communities in Tanintharyi are likely to depend more on marine and fishery resources.

14.8.5 Fuelwood

Fuelwood is the major energy source for domestic cooking in mangrove areas and buffer zones in the delta. It is also one of the major products in mangrove community forestry as timber, posts, and poles are limited in community forestry areas. In Pyapon Township, mangroves also provide the energy used for drying fish on bamboo racks on the shore. Fuelwood, therefore, has long been a significant income source for the livelihood of local people even though most fuelwood is illegally logged from reserved forests and national parks in the delta (GGKP 2020). Most community forests are established on ex-agriculture lands by planting fast-growing mangrove species such as *Avicennia* species.

14.8.6 Mangrove Tourism

Tourism is one of the fastest-growing industries in Myanmar, especially since 1996 when the Myanmar government promoted a tourism campaign *Visit Myanmar Year*. The number of tourists visiting Myanmar demonstrated a growing trend in the past 5 years, and in line with this, the EU declared that Myanmar is the 2014s world's best travel destination, indicating increased interest in Myanmar tourism. The Lampi Marine National Park in the Myeik (Mergui) Archipelago is one of many national parks the government wishes to promote as places to visit. The local people, the Moken, are glamourized in the western press as "sea gypsies" (Zöckler and Aung 2019).

In the Ayeyarwady delta, the Meinmahla Kyun Wildlife Sanctuary, the ASEAN heritage park, is also one of the nature-based tourism sites. Recently, the mangroves associated with the well-known beach such as Chaung Tha and Shwe Thaung Yan have become tourist-attractive sites. Mangroves and its associated coastal ecosystems, corals and dunes, marine life, and Moken culture are the main tourism attractions. War Kyun resort and its mangroves are tempting for nature-based tourists. Although there is a potential site of mangrove tourism in Rakhine State, Wunbaik Mangrove Reserve, the region has long been under security risk. Recently however, after the political conflict from February 2021, as well as the covid-19 pandemic, the tourism industry has been sharply in downturn.

14.9 Threats and Conservation

14.9.1 Threats

14.9.1.1 Fuelwood and Wood Products

Demand for firewood is not just in mangrove areas but also in the whole forest sector in Myanmar. According to the development of Asian countries, by 2015, electricity use per capita has been the lowest capacity among Asian countries. Currently 69.2% of households are still dependent on the consumption of fuelwood and 11.8% on charcoal. In terms of mangroves, it is locally said that more than half of the mangroves have been degraded and depleted due to fuel consumption since three decades ago. Electricity shortage in the capital city, Yangon, caused an increase in consumption of fuelwood produced from the mangroves in the Ayeyarwady delta. Charcoals produced from *Rhizophora* species were one of the best at that time, but now those species have become rare.

According to firewood surveys, 5 tons of fuelwood per household per year for rural communities from 20 villages in the vicinity of the project site are consumed by local communities (JICA 2017). At the same time, the 10-year Pyapon district forest management plan has shown that the consumption of fuelwood in Bogale Township is 2.5 tons of fuelwood per household per year for rural communities and 1.4 tons for urban communities. In fact, the primary purpose of mangrove-reserved forests in the first delta working plan was to provide fuelwood and basic needs, like poles and posts for construction, for local people who settle in the area no farther than 5 miles from the reserved forests. However, with increasing population density, the mangroves cannot afford the demand and supply as there is no electrification and limited alternative substitute fuels. The Ayeyarwady delta is the most populated region in Myanmar according to the Population Census (2014). Then, because of the overexploitation of firewoods not just for local needs but also trade and commercial purposes, the remaining patches of mangroves have been intended for conservation and biodiversity.

More seriously, high demands of firewood by offshore fishing rafts can accelerate the degradation of mangroves in the winter season as people increasingly collect firewood and sell them to the whole sale at the corresponding points in the villages. Without fulfilling such high demands and seeking alternative fuels, the sustainability of mangroves will fail. In reality, 3–5 years after the mangrove plantations were established by the Forest Department and other national/international organizations, the immature plantations happen to be cut for firewoods both for basic needs and commercial purposes. Regarding national policy upon solving the demands of firewood, NDC's (nationally determined contribution) commitment by Myanmar is to distribute 260,000 efficient stoves by 2030 and to establish community forestry to reach 2.27 million acres by 2030. However, there exist a number of challenges to accomplish these targets, and a strategic plan is needed for real implementation on the ground.

14.9.1.2 Rice Fields, Shrimp Farming, and Salt Pans

Encroachment of rice fields on the mangroves of the Ayeyarwady delta is common, and 87.6% of mangroves that have been already cleared are due to rice fields (Richards and Friess 2015). For instance, in one of the reserved mangroves in the Ayeyarwady delta, 69.35% of mangroves were lost by 2015 from 1990, and most of them, were due to rice fields. The mangrove areas are rich in nutrients, and part of larger wetland systems, making them attractive as agricultural areas. Local communities have limited choice to earn their living by other alternative job opportunities, and clear cutting mangroves and cultivating rice are supposed to be the only livelihood they rely on. In fact, local people have been quite aware of mangroves for their support to the society as fishery breeding ground and coastal protection functions. However, they need short-term benefits and cannot wait for long-term intangible benefits from mangroves to address their immediate needs. In the past, mangroves were supposed to be wastelands with unproductive muddy flats and

Fig. 14.4 Extensive shrimp pond in the Ayeyarwady mangrove (Photo: Toe Aung)

mosquito breeding grounds and thus cleared to expand rice fields for rice production campaigns by the corresponding ministries in coordination with development partners. Big dykes were constructed to block the intrusion of salinity. This made the mangrove areas unregulated by the flow of brackish water, and after that, the survival of mangroves was no longer viable.

Similar to encroachment of rice fields, shrimp farming by clearing mangroves is another major concern (Fig. 14.4). This aquaculture is intended to produce tiger prawns, but the extensive aquaculture operations are most often constructed for export. In Rakhine State, both rice cultivation and shrimp farming are carried out seasonally and alternatively. Especially, at the southern border of Pyindaye reserve mangroves in the Ayeyarwady delta, a couple of thousand acres of mangroves have been cleared for shrimp farming practices. Shrimp farm activity alone has been responsible for the loss of 38% of the world's healthy mangroves; the percent climbs to 52% if all agricultural activities are counted (Ellison and Farnsworth 1996).

The mangrove areas in the Ayeyarwady delta and Rakhine State are prized for salt production in particular due to their closeness to the sea. The salt production is granted for license by the mining sector. The lands, although covered with mangroves, are managed out of the permanent forest estate (PFE) but are prone to change into other land uses. As a result, large areas of mangroves have been cut, and the hydrology has been disrupted to intensify commercial production of shrimp and other species, cultivate agricultural crops, and create salt ponds.

14.9.1.3 Climate Change and Natural Disasters

According to the Munich Re's 2015 Global Climate Risk Index, Myanmar is ranked the second highest cyclone-vulnerable country in the world. UNEP (2013) describes (a) an increase in mean temperature (~0.08 °C per decade) with the prevalence of drought events; (b) an increase in the intensity and frequency of cyclones and strong winds; (c) an increase in overall rainfall with a declining trend in some areas and late-onset and early termination of the southwest monsoon, with rainfall variability including erratic and record-breaking rainfall events; (d) an increase in the occurrence of flooding; and (e) an increase in extreme high temperatures. Under such a climate risk situation, Cyclone Nargis 2008 is the deadliest storm in the history of Myanmar. The livelihoods of local people were severely affected, and the mangroves were also destroyed. The mangroves had also been devastated by the cyclone, but the impacts seemed to be more severe near human interventions. The possible reason is that the ecosystems of mangrove are dynamic and highly resilient (Alongi 2008), and the mangrove vegetation resilience after the cyclone has also seen high recovery. Local people had high demands of wood to reconstruct their shelter/houses, and their cuttings of mangroves at that time were neglected without law enforcement. In spite of the fact that there is no data to be approved, the woody vegetation of mangroves in the Meinmahla Kyun Wildlife Sanctuary has significantly changed to bush and scrub vegetation after Cyclone Nargis.

14.9.1.4 Coastal and Delta Development with Human Settlement

The landscape of the Ayeyarwady delta has for a long time been without systematic urban and rural planning and an integrated approach. Sectors have been disintegrated with limited coordination. The overlap of freshwater fishery law and forestry law has not been solved yet. The enforcement of forestry law is weak because of insufficient human and financial resources for effective conservation and management measures. Although the mangroves have been reserved for many decades, illegal encroachment of rice fields has not been well prohibited, and illegal activities are still carried out.

Land-use conflicts among forestry, fishery, and agriculture have been due to unclear land-use policy. The MOECAF (Ministry of Environmental Conservation and Forestry) (now MONREC) led the reformulation of national land-use policy, and it was issued in January 2016 but needs to be implemented on the ground by relevant authorities and by decision-makers. There are two major concerns from landscape perspectives: one, erosion is seriously happening along the tributaries, streams, and rivers, and two, the villages settled along the highly eroded riverbanks and wind-exposed environment without windbreak or green shelter. Thousands of people died in Cyclone Nargis, and it is commonly said among local communities to be due to the clearance of mangroves in the reserved mangrove forests.

14.9.1.5 Improper Revenue Collection System

Inside the mangroves in Myanmar, nonwood forest products (NFWPs) are allowed to be extracted for basic needs and commercial use. Revenue collection is one of the hidden issues in mangrove deforestation. The revenues collected from each area should be followed in line with the actual production of the NWFPs. If not so, more pressures of cutting mangrove resources for fuelwood, posts, poles, and timber demands cannot be addressed. For *Sonneratia* and *Avicennia* species planted in the project, the size of girth gained for 5–7-year-old plantations is harvestable in favor of illegal cuttings. Decision-makers need to be aware to stop excess revenue collections from fuelwood, poles, and posts on mangrove resources in improper ways. Therefore, revenue collection needs to be carefully dealt with in practice. Positively, in recent years, the planned revenue collection from mangrove resources has been reduced, which support restoration of mangroves naturally from serious degradation. It should be hereby noted that mangroves should be intended for conservation rather than production-based management because of its high ecosystem productivity and values.

14.9.1.6 Grazing

Grazing in mangrove areas is not seen as a serious issue to be addressed. However, the restored mangrove plantations are at risk of grazing buffaloes in some parts of the Ayeyarwady delta. The species mostly consumed and grazed are *Avicennia officinalis* and *A. marina*. Overgrazing by goats, camels, etc. is one of the common disturbances in the Middle East countries (Lewis 2006).

14.9.2 Conservation and Management

Since the British colonial days, the mangroves in Myanmar have been managed within the permanent forest estate (PFE) that includes reserved forests, protected public forests, and protected area systems. The mangrove area extent in Myanmar is estimated at approximately 1,119,284 acres (FAO 2020), in which the permanent forest estate has been established as 657,983 acres; approximately 59% of mangrove cover over the Myanmar coasts (FAO 2020) (Forest Department, 2020 unpublished). The rest of the mangroves (41%) is out of the permanent estate, and it has been at risk of land grabbing for long-term cash crops, resorts, and shrimp farming. According to the Forest Department figures (unpublished 2020), the total mangrove PFEs are 657,983 acres: 88,106 acres in Rakhine State, 228,740 acres in Tanintharyi Region, 334,917 acres in Ayeyarwady Region, 6089 acres in Yangon Region, and 131 acres in Mon State. In Yangon Region and Mon State, there were no protected public mangroves until 2015, and the protection of mangroves has been raised by the claim of local communities to protect their lives from the tropical cyclone. However, like the mangroves in the Ayeyarwady delta and Rakhine State, these mangrove PFEs are facing a lot of challenges in deforestation and fragmentation due to the encroachment by the increasing population. Since 1995, community-based mangrove management, called "community forestry," has also been initiated, and now the establishment of mangrove community forests has been issued to more than 10,000 acres.

Mangrove-protected area is also one of the PFE types. There are two mangrove-protected areas: one in the Ayeyarwady delta and one in the Myeik Archipelago. Comparing the reserved forest and protected public forests in mangroves, mangrove-protected areas have shown as more effective management perspectives with reference to the experiences derived from the impacts of Cyclone Nargis in 2008. One of the mangrove-protected areas called "Meinmahla Kyun Wildlife Sanctuary" established in 1993 was fully covered with mangrove forests. It supports one of the largest remaining mangrove areas in the delta, where mangrove ecosystems have declined due to the major activities of rice cultivation and human settlement, although most of the true mangrove species have been already replaced by mangrove date palm (*Phoenix paludosa*). It is also a Ramsar Wetland of international importance, representing an ASEAN Heritage Park, as well as its substantial carbon sequestration capacity and supporting globally threatened species such as the critically endangered hawksbill turtle (*Eretmochelys imbricata*), mangrove terrapin (*Batagur baska*), and the last estuarine habitat in Myanmar for the saltwater crocodile (*Crocodylus porosus*), it holds significant cultural and historic value, a kind of spirit, locally called "U Shin Gyi Nat" according to the myths and pilgrimages for local communities living in the brackish water environment, that is largely related to the mangrove environment.

Another mangrove-protected area is located in the Myeik Archipelagos, called "Lampi Marine National Park," which was established in 1996 that covers a group of islands in the Myeik Archipelago in the Tanintharyi Region of southern Myanmar. It is the only marine national park with richness in coral reefs, seaweeds, mangroves, and seagrass beds which are important food for threatened species such as the green sea turtle and the dugong.

14.9.3 Afforestation

Recently the Myanmar Reforestation and Rehabilitation Plan 2018 to 2027 by the Forest Department has started establishing more mangrove plantations all over Myanmar coasts. Its target for 10 years is set to establish almost 29,690 acres, meaning 3000 acres of mangrove plantation every year in the degraded and depleted mangroves over Myanmar coasts. Planting mangroves started in 1982, and the total number of mangrove plantations until 2020 is 62,260 acres in the Ayeyarwady delta since 1982, 3145 acres in Rakhine coastline since 2007, and 550 acres in Mergui archipelagos in Tanintharyi coastline since 2014. Mangrove plantations are aimed to

Fig. 14.5 Propagule collection and sale by the mangrove community forestry (Photo: Myo Myint)

restore mangrove ecosystems in the depleted mangrove areas, fulfill the subsistence needs of local communities, improve the health of the natural environment, establish mangrove windbreaks for the safety of local communities, and adapt the livelihoods of local people in harmony with climate change. The success of mangrove plantation, however, is questionable and needs to be evaluated.

Planting with seed pots in plastic bags is common in mangrove plantation establishments, and it is also a current method with standard norms for the mangrove plantation by the Forest Department. INGOs (international nongovernmental organizations) and NGOs (nongovernmental organizations) working for mangroves are also planting in a variety of ways such as direct seed sowing, direct seeding of propagules, and bare root planting. The interesting thing to note for mangrove planting is that a million of wild seedlings were unofficially used in a thousand acre of mangrove plantation establishment after Cyclone Nargis. It could be considered one of the natural and cost-effective ways of mangrove planting if caution is taken not to disturb the surrounding natural mangrove flora and fauna. For the community forestry user groups in the Pyapon Township in the Ayeyarwady delta, selling mangrove propagules for the mangrove planting agencies has become one of their major livelihood's incomes (Fig. 14.5).

14.9.4 Legislation

The National Forestry Master Plan (NFMP) formulated for a 30-year period from 2001–2002 to 2030–2031 partly cover mangrove conservation and management. Accordingly, Community Forestry Instructions' (CFIs) issued FD (1995) is a remarkable initiative in the aspects of partnership, participation, and decentralization in managing the forests including coastal forests and mangroves in Myanmar. The instruction grants the local communities' trees and forest land tenure rights for an initial 30-year period that is extendable based on the success of implementation. The FD provides technical assistance and plays the leadership role in the exercise of community forestry. To promote mangrove conservation, restoration, and management, MONREC (Ministry of Natural Resources and Environmental Conservation) is the main agency responsible for implementing the national policy on nature conservation in Myanmar; however, other ministries, such as the Ministry of Agriculture, Livestock and Irrigation (MOALI), also share responsibility and accountability for biodiversity conservation. In this context, the National Coastal Resources Management Committee (NCRMC) has been recently formed in an attempt to consolidate marine and coastal resources conservation activities, largely focusing on mangrove ecosystems conservation, at local and national levels. The committee is chaired by the vice president (1) and includes 21 members, thus being one of the most important platforms for mangroves and its associated marine and coastal ecosystem. Table 14.9 shows the enabling legal framework that supports the mangrove sector development and conservation.

14.10 Case Study: Perspectives of Awareness, Attitudes, and Participation of Local Stakeholders in Mangrove Ecosystem Conservation and Management

14.10.1 Background

Humans cannot live just for themselves; instead, they live and support each other and gather with other species in the ecosystem (Sudarmadi et al. 2001). However, they are becoming densely populated and exploit natural resources unwisely, with the net effect that they now have to confront the critical problem of environmental degradation. As one of our major environmental concerns, mangroves are disappearing at a rate greater than or equal to the adjacent rainforests (Valiela et al. 2001), and their deforestation has become critical to be tackled in our time. The causes of the loss have been mainly attributed to anthropogenic activities (FAO 2007; Walters et al. 2008), such as conversion to agriculture, aquaculture, urban development, salt pans, transmission lines, and mining (ISME 2004). Humanity is therefore a major force in global change and shapes ecosystem dynamics ranging from local environments to the biosphere as a whole (Folke 2006).

Table 14.9 Myanmar's existing policies, strategies, and frameworks and main multi-/bilateral treaties and agreements

National development framework	Myanmar's market-oriented policy scheme (1988) Myanmar Agenda 21 (1997) Millennium Development Goals (MDG) (2006) National Sustainable Development Strategy (NSDS) (2009) 30-year National Forestry Master Plan (2001–2002 to 2030–2031)
Institutional framework	National Coastal Resources Management Committee (NCRMC), Working Committee, Advisory Committee, Coastal Regional/State Committees and Coastal District Committees Ministry of Natural Resources and Environmental Conservation ASEAN Committee on Disaster Management (ACDM) National Disaster Preparedness Central Committee (NDPCC)
Supporting policy and planning framework	Myanmar Forest Policy (1995) Community Forestry Instruction (1995) National Environment Policy (1994) Myanmar Action Plan for Disaster Risk Reduction (MAPDRR) (2009–2015) Myanmar Action Plan on Disaster Risk Reduction, Preparedness, Relief and Rehabilitation (2017)
Main treaties/agreements	United Nations Framework Convention on Climate Change (UNFCCC) (1992) Convention on Biological Diversity (CBD) (1994) The Kyoto Protocol (1997) Hyogo Framework for Action (HFA) ASEAN Multi-sectoral Framework on Climate Change Agriculture, Fisheries and Forestry towards Food Security (AFCC)

For most of human history, the natural world has been protected from most disruptive human influences by virtue of our relatively humble technology, local laws, and cultural or religious taboos, all of which have prevented overexploitation. The loss of traditional knowledge about resource use is one of the central problems of our time (McNeely 1993). Local environmental knowledge and awareness can be a powerful mechanism in mangrove restoration and management. Local people as "critical social capital" and the mangroves as "critical natural capital" have lived side by side for hundreds of years. Local people, without doubt, are of crucial importance in shaping their surroundings, and they can either destroy or create a better environment. The hypothesis in the case study is whether or not mangrove degradation is due to stakeholders being unaware of mangrove conservation.

14.10.2 Study Site

The communities in two separated mangrove tracts of mangroves, Pyindaye Reserved Forest (PRF) and Kadonkani Reserved Forest (KRF), are the focus of this case study. Both are next to the Meinmahla Kyun Wildlife Sanctuary, a totally protected area. Kadonkani RF was in the eye of the path of Cyclone Nargis in 2008 and was severely affected, while Pyindaye RF was outside the eye of the cyclone path and was less affected. Five villages in each were selected. The study villages in Kadonkani RF were Atwinmayan, Kyeinchaungkyee, Gwechaungkyee, Ngapokethin, and Padegaw, while those in Pyindaye RF were Anaukmee, Ashaepya, Gawdu, Htaungyitan, and Thameinpale. The population of the former five villages was subject to severe devastation caused by the cyclone. Figure 14.6 shows that almost half of the population in Kadonkani mangroves was decimated by the deadly cyclone, whereas the latter five villages in Pyindaye mangroves did not undergo any change to their social structure and there was no loss of human life.

The analysis was carried out by dividing awareness, attitudes, current participation, and future participation prospects based on location (the level of cyclone impact), gender, education, and livelihood or occupation. Data was generated by conducting semi-structured interviews with local respondents as well as through field-based observations. Based on the preliminary survey of the area, local

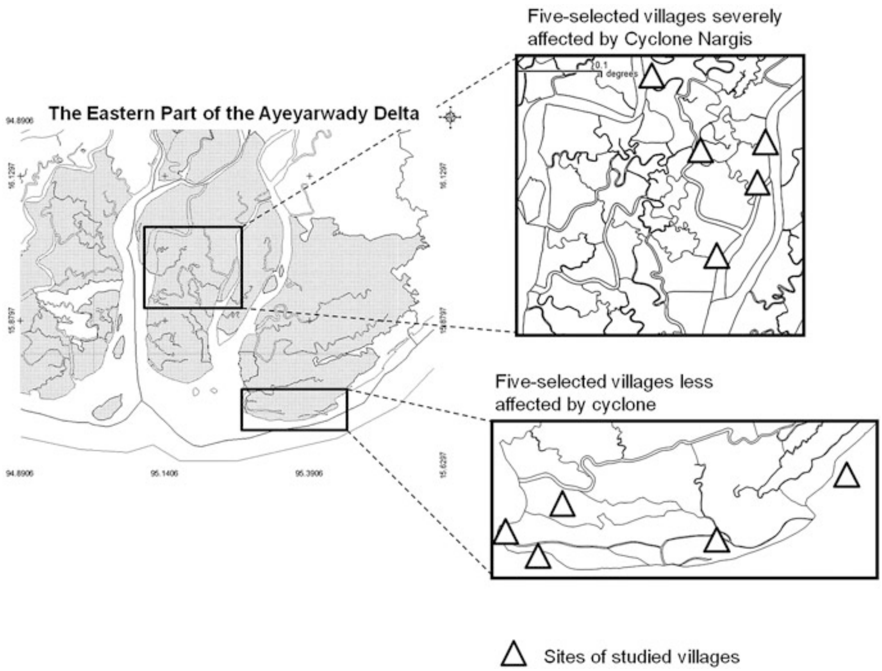

Fig. 14.6 Map showing the location of the study villages in the two separate regions

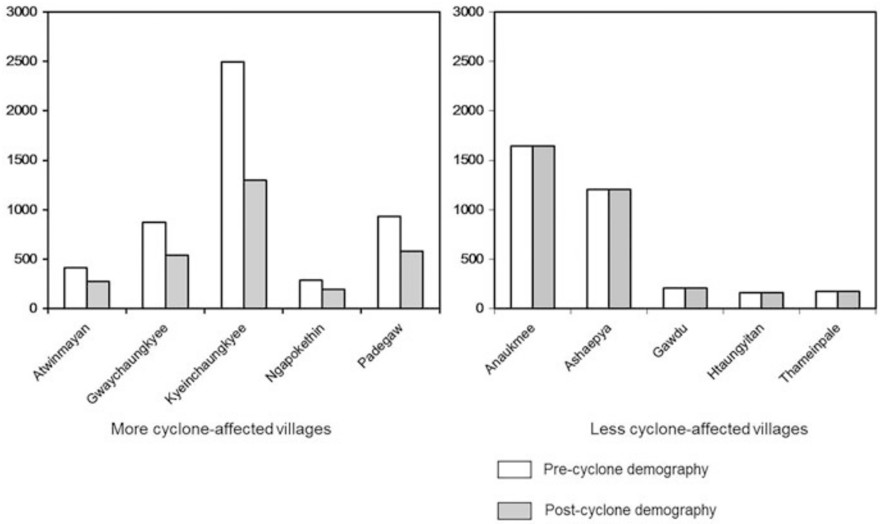

Fig. 14.7 Pre-cyclone and post-cyclone population sizes of five severely cyclone-affected villages in the Kadonkani mangroves and five less cyclone-affected villages in the Pyindaye mangroves

stakeholders were divided into six main categories according to their livelihood patterns, that is, fishermen, farmers, casual laborers, workers, shrimp pond owners, and salt pan owners. All of the groups are suggested as mangrove key stakeholders since they depend mainly on the mangroves either directly or indirectly (Fig. 14.7).

14.10.3 Awareness and Attitude on Diverse Livelihood Patterns

The results have shown that there is a significant difference between the two regions with their different cyclone impact extents while education, gender, and occupation were not considerably significant. Interesting results were derived from the observations of awareness and attitudes with the patterns of livelihood of local respondents, shown in Table 14.10. Awareness is highly significant among the different livelihoods, and after excluding workers, a null hypothesis was accepted. Therefore, the workers, that is, the outsiders or recently migrant people to the mangrove area, had the most limited awareness of the mangrove environment. In terms of attitudes, highly significant values were found among different livelihood patterns of people. The extent of the differences can be seen clearly, particularly for shrimp pond owners. It was evident that shrimp pond owners had a limited willingness to show the importance of mangrove conservation. Overall, despite the fact that there was considerable awareness and attitudes of mangroves by all local stakeholders, there

Table 14.10 Comparison of awareness and attitudes in terms of different patterns of livelihood

	Patterns of Livelihood												
	Farmers		Fishermen		Casual laborers		Workers		Shimp-pond owners		Salt-pan owners		
Awareness	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	*p*-value
Observation I	83	1	61	4	79	5	20	7	24	2	26	0	**0.0002***
Observation II	84	0	65	0	85	1	24	4	26	0	26	0	**0.0000***
Observation III	67	16	54	11	75	12	20	8	18	7	26	0	0.0523
Observation IV	78	6	60	5	81	5	22	6	24	1	26	0	0.0519
Observation V	84	0	65	0	86	1	28	1	25	1	26	0	0.3083
Attitude	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	Yes	Limited	
Observation I	83	0	64	0	83	3	23	3	25	1	22	2	**0.016***
Observation II	56	27	38	27	73	13	21	6	7	18	21	5	**0.0000***

Note: The significant differences (*$p < 0.05$) in awareness and attitudes are represented in bold. Variations in response rates are the result of missing answers or missing information in the answer sheets (Adapted from Aung (2012)) was a slight difference between the mobile communities and the immobile or settled ones.

Cornwall (2008) investigated that, in environmental awareness, there are significant differences in occupation, location, land tenure status, sex, caste, religion, or tribe, although they are related in different ways. However, the current case study of location, education, and gender was not considerably significant. It was hypothesized that the mangroves in the mega-delta region have been continuously decreasing because one of the factors is local people's lack of awareness about the mangroves. This assumption is rejected in the present case study; the majority of people living in the mangrove environment illustrated an appreciable level of knowledge and awareness about the mangroves. Their lifelong experience of the dramatic decline in the number of fish available to catch and the limited availability of fuelwood to meet their subsistence needs could have made them realize the value of the mangrove ecosystem. Most importantly, in 2008, their personal experience of Cyclone Nargis, the deadliest tragic story over the history of Myanmar, and the concomitant loss of human life and property were unforgettable. It is, therefore, not surprising that the majority of local respondents were aware of the crucial importance of the mangroves in terms of their life-supporting and life-protecting functions. However, in the present study, the key finding pertained to the recent migrants and remote resource users, that is, the mobile/migrant people, meaning not native to the current mangrove sites; in particular workers and shrimp pond owners have less awareness and attitudes compared to the immobile ones who have settled in the mangroves since at least a decade.

In terms of the workers, they seemed to be slightly less aware of the importance of the mangroves when compared to other local respondents. This community group, which comprises mostly recent migrants, relies partially on the mangroves because, although most of them are not direct mangrove cutters, they directly use the mangroves for fuel and construction materials. The second community group that showed limited attitudes compared to the other groups was the businessmen who operate shrimp farming. Some of them were reluctant to accept the importance of the mangroves as it was their perception that mangrove restoration and conservation would negatively affect their business. Mangrove habitats need to be cleared for the establishment of shrimp ponds, and the businessmen claimed that the shade of the mangrove canopy causes a decline in the shrimp production rate as well as a reduction in the size of tiger prawn (*Penaeus monodon*). This is a direct conclusion derived from their experience. This fact should not be supposed as a hindrance in mangrove restoration measures. The critical point here is how to draw up a strategic management plan that integrates both social and ecological needs of all relevant stakeholders.

With respect to the responses of local stakeholders, some are shown in Box 14.1, indicating that if restored mangroves were privately owned, the local stakeholders would have a greater desire to participate in restoration measures. According to Addun and Muzones (1997), there are five basic principles that are required for community-based resource management: empowerment, equity, sustainability, systems orientation, and gender fairness.

Box 14.1 Concluded Answers of Respondents with Respect to Questions About Their Restoration Participation Motivations and Limitations

Motivations to participate in mangrove restoration	Limitations to participate in mangrove restoration
• "If we plant mangroves, we can get shelter from storms in future" • "Planting mangroves can regulate the climate again" • "If the extent of mangroves increases again, fish, shrimp, and crabs will flourish once more" • "I would like to secure fuelwood and plants for household use in the future, so I want to plant mangroves" • "Under tree shelter, we have better lives" • "I do not want there to be scarcity of fuelwood, I want to plant mangroves" • "We want large adult trees to protect our lives from storms" • "It is our experience that, if we plant mangroves, they save our lives" • "(I want it) to be green again the same as before" • "We have to participate because we are asked to do it by organizations in force"	• "I have to struggle for my family's livelihood daily—if there is no income today, there is no food for tomorrow" • "Time is too limited to participate in planting because I have to go fishing" • "Not enough people at home to participate in the restoration" • "That is not private (ly owned)" • "Only if I can get that land privately, then I can protect it" • "Too busy doing my own business of fishing and farming." • "I am too busy with my shrimp pond business" • "I am not a man, just a widow, so it's difficult to take part" • "(There is) no household leader at home" • "I am not quite healthy (enough) to participate in planting activities" • "I am getting old"

The current case study first attempted to hypothesize that local people have limited awareness and attitudes with respect to the mangrove environment, and hence they did not actively participate in restoration processes. Indeed, we sought to establish that this factor was one of many reasons that caused the degradation of the mangroves. The hypothesis is rejected in the present case study as it was demonstrated that most of the local stakeholders have fairly sufficient awareness and attitudes to enable active participation in mangrove restoration although there are slight differences between the different stakeholders. In particular, poorer attitudes were observed in some migrant communities compared to the settled communities. This slight difference may not be an issue, and the key point is that restoration strategy through the participation of all local stakeholders is needed in order to restore, reforest, and rehabilitate the mangroves. However, local participation in restoration measures is still limited. In developing a management strategy, participatory management should be incorporated by prioritizing the subsistence needs of the local people plus economic benefits.

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