

Mangrove stands of Andamans *vis-à-vis* tsunami

S. Dam Roy* and P. Krishnan

*The earthquake (9.0 Richter scale) which struck Andaman and Nicobar Islands on 26 December 2004 and the consequent tsunami have caused considerable change on the mangrove stands of Andamans. The tidal waves that swamped the mangrove stands have affected the giant fern *Acrostichum aureum* and the aquatic sedge *Fimbristylis littoralis*. The true mangroves, viz. *Rhizophora* spp, *Bruguiera* spp, *Avicennia* spp, *Sonneratia* spp, etc. have also got affected in various degrees based on their physiological response to the continuous inundation/exposure under the changed scenario. In South Andaman, in particular localities 30–80% of mangrove stands got affected. In Middle Andaman the impact is negligible, whereas in the North Andaman due to the elevation of land, the sea water is not reaching some of the mangrove stands. Some visible impact has also been felt in the habitat of various fin fishes and shell fishes .*

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ACCORDING to the latest estimate of the Forest Survey of India¹, the total area under mangrove vegetation in India is 4827 km². Out of this, 966 km² area of mangrove vegetation occurs in Andaman and Nicobar (A&N) Islands (i.e. 20% of the total mangrove area of the Indian territory). In Andaman district, the area under mangroves is 929 km²; while in Nicobar district mangroves occupy only 37 km². Area wise, A&N Islands are second in the country after West Bengal, but as far as density and growth are concerned, mangroves of these islands are the best in the country². Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks, the width ranges from 0.5 to 1 km. This salt-tolerant community is found on rocky shores exposed to tidal action and sometimes is also found growing in tidal mudflat. Luxuriant mangroves are seen in Shoal Bay (South Andaman), Yerrata (Middle Andaman), Austin Creek, Kalighat Creek and Cadell Bay (North Andaman)³.

The earthquake of 9.0 on the Richter scale, which struck Andamans on 26 December 2004 and the subsequent tsunami have brought about devastating human tragedy and considerable loss to the flora and fauna of these islands. More particularly, the sudden surge of sea water has inundated the inshore of the mangrove stands, causing irreparable damage to the mangrove and mangrove-associated plants of South Andaman. In South Andaman, due to subduction of the land by about 1.25 m, the level of submergence due to tidal influence has also increased. However, in the Middle and North Andamans, the situation took a peculiar turn, wherein the land has risen to the extent that even during spring tide (when the sea water usually rises

to 2.40 m above mean sea level), sea water was not reaching the mangrove zone, causing a situation that the roots of the true mangals such as *Rhizophora* spp., *Bruguiera* spp., etc. remained exposed even during the highest high tide.

Impact of tsunami on mangrove stands of Andamans

South Andaman

After the tsunami struck different parts of A&N Islands on 26 December 2004, the following observations were made.

In Sipighat creek area, it was observed that the *Acrostichum aureum* stand was completely submerged with sea water and completely turned brownish, indicating that it had died. A complete patch of aquatic sedge, *Fimbristylis littoralis* got inundated and remained submerged during the earthquake-induced tidal waves. It continued to remain in that condition due to subduction of land mass, which in turn rose the level of water to 1.25 m more than the normal tides in South Andaman, and ultimately perished the patch of sedge (Figure 1).

The mangrove associated plants like *Acanthus illicifolius* and *Acanthus ebracteatus* got submerged with the surge of sea water having loads of silt, which were then deposited on the leaves. Although some of the leaves turned brown, the plants did not die. Most of the affected plants were located in the area where salinity was low almost throughout the year, but due to sudden surge of sea water, the plants got inundated with high saline water. High salinity caused physiological stress to the plants and hindered photosynthetic activities. The roots remained submerged and were not exposed at least 2–4 times a day during low tide and subsequently the plants died.

Similar observation was made in case of *Rhizophora* stands opposite to the creek areas of Sipighat, South Andaman.

The authors are in the Central Agricultural Research Institute, Port Blair 744 101, India

*For correspondence. (e-mail: sibnarayan_damroy@yahoo.co.uk)

man. In these stands, sea water entered only during high tides. *Rhizophora* trees bore the brunt of the surge of sea water, which rose to about 2 m height due to the tsunami. Sea water inundated the leaves as well as roots of the tree for considerable time, as there has been a rise in the level of sea water by 1.25 m and salt got accumulated on the leaves of trees, causing the leaves to fall. Further, scorching of the leaves by heat and settlement of silt on them compounded the problem and the plants ultimately perished (Figure 2).

Similar observation was made by McMillan⁴ on tidal waves and storm surges. Situated in coastal areas, mangroves are naturally subjected to damaging effects of tidal waves and storm surges; when these occur, the transient period of deep inundations and more importantly, the strong water movement is likely to cause more damage than waves in a storm. The felling of trees, scorching of the nonsalt-tolerant species, erosion of fringes and deposition of silt and other materials can be severe and extensive. Water turbulence likewise affects seedling establishment. Mik-luchio-Mcclay⁵ observed that tidal waves caused extensive destruction of coastal vegetation (unspecified) along the North Coast of the Huon of New Guinea in 1885. These



Figure 1. Mangrove associates – Giant fern, *Acrostichum aureum* (A) and sedge, *Fimbristylis littoralis* (B) affected by high line water brought about by tidal surge.



Figure 2. *Rhizophora* tree and *A. aureum* affected by high saline water brought by tsunami.

presumably caused destruction of mangrove communities along the coastline. Tindle⁶ recorded legends relating to destruction of mangrove communities by tidal waves on Bent Ink Islands, Queensland.

Mature mangrove ecosystem is sensitive to minor changes in its substratum. In this particular case, changes in salinity of mangrove waterways and continuous submergence of the mangrove in sea water brought about sudden change in the environment. The mangroves were unable to make physiological adjustment to the changed situation due to their own limitations, which have been described earlier. Hence the fall of leaves made the plants completely barren, thereby hampering the photosynthetic activities and consequently the plants died. This could be observed in the mangrove stand opposite to the creek area of Sipighat.

In Chouldari, South Andaman, similar condition was observed with respect to *A. aureum*. Here also, it was observed that *Acrostichum* plants which were adjusted to low saline water (2 ppt), got severely affected due to the sudden surge of high saline sea water during the tsunami. Due to continuous submergence, all the trees turned brownish, suggesting that they were dead. The *Avicennia* stands of the Chouldari village present in the seafront were not affected by the tsunami. In fact, some of the trees were actually thriving well. *Nypa fruticans*, the palm-like trees which border along the creek of Sipighat mangrove stand, were also severely affected, primarily because they are not amiable to high salinity. The effect of the tsunami has also been felt severely in the mangrove stands of Mahatma Gandhi Marine National Park, Wandoor. The *Rhizophora* stands situated in the inward areas (adjusted to low saline microhabitat) were affected due to the surge of high saline sea water. After remaining submerged due to subduction effect, the trees shed their leaves and are dying. Some of the *Pandanus* trees were observed to be physically uprooted by the tidal waves and the leaves are also rotting. In Minnie Bay area, the mangrove stands were inundated by tidal waves of about 3 m height. Mangrove stands opposite to the sea were severely affected. All the plants lost their leaves, as the roots of the trees remained continuously exposed to sea water due to the subduction affect. The impact of the tsunami on mangrove stands of Andamans was noted (Table 1; Figure 3).

According to Noaks⁷, 'The *Rhizophora* forests mark the climax of the mangrove succession and cover two-thirds or more of the total areas of the swamps. The conditions necessary for their existence are inundation by ordinary high tides, but with dry periods of 4–8 days twice in each month at neap tides, and a soil that has been aerated and enriched to a considerable depth'.

Avicennia tree was found to be more tolerant to thrive in the altered condition the tsunami brought due their secretory nature than *Rhizophora*. Another permanent feature that the earthquake has brought about is that the land mass of the South Andaman has gone down by 1.25 m, that is subduction has taken place. With the result, the mangrove

Table 1. Impact of tsunami on mangrove stands of Andamans

Mangrove stand	Dominant mangrove species	Observation
South Andaman		
Sipighat junction	<i>Rhizophora mucronata</i> <i>R. apiculata</i> <i>Avicennia marina</i>	80% of <i>Rhizophora</i> spp. was affected in low saline microhabitat and died due to continuous submergence (subduction of land) and tsunami. <i>Avicennia marina</i> are thriving.
Minnie Bay	<i>R. mucronata</i> <i>R. apiculata</i> <i>A. marina</i>	40% of <i>Rhizophora</i> spp. was affected and most of them died due to continuous inundation (subduction of land) and tsunami. <i>A. marina</i> are thriving.
Chouldari	<i>R. apiculata</i> <i>A. marina</i> <i>R. mucronata</i> <i>Sonneratia alba</i>	30% of <i>Rhizophora</i> spp. was affected and most of them died due to continuous submergence (subduction affect) and tsunami. <i>A. marina</i> and <i>S. alba</i> are not affected.
Wandoor	<i>R. apiculata</i> <i>A. marina</i> <i>R. mucronata</i>	30% of <i>Rhizophora</i> spp. was affected in low saline microhabitat and most of them died due to continuous submergence (subduction affect) and tsunami. <i>A. marina</i> are not affected.
Middle Andaman		
Uttara	<i>R. apiculata</i> <i>C. tagal</i> <i>R. mucronata</i> , <i>A. marina</i>	Mangroves are healthy and are not affected.
Rangat	<i>A. marina</i> <i>A. officinalis</i> <i>Exoecaria agallocha</i>	Mangroves are healthy and are not affected.
Rangat Bay	<i>A. marina</i> <i>R. apiculata</i> <i>R. mucronata</i>	Mangroves are healthy and are not affected.
North Andaman		
Mayabunder	<i>R. apiculata</i>	Mangrove roots remain exposed even during spring tide.
Karmatang, Danapur, Dobidehra, Baludehra	<i>R. mucronata</i> <i>A. marina</i>	
Diglipur	<i>A. marina</i>	Mangrove roots remain exposed even during spring tide.
Durgapur	<i>R. apiculata</i> <i>R. mucronata</i>	
Ariel Bay	<i>R. apiculata</i> <i>R. mucronata</i> <i>A. marina</i>	Mangrove and reef areas remain exposed even during high tide.



Figure 3. *Rhizophora* tree affected by continuous inundation due to rise in water level following subduction of land at Minnie Bay, South Andaman.

which remained exposed during normal low tide, now remains deeply submerged throughout the period in some areas.

North Andaman

The impact of the earthquake in North Andaman is opposite to that in South Andaman. Due to earthquake, the land mass in South Andaman has got elevated to the extent that even during the highest high tide, sea water does not reach the roots of *Rhizophora* trees. This changed scenario may result in succession by other mangrove plants in these areas. The dry condition will suit *Bruguiera* spp., *Aristolochium* spp., etc. (Figure 4 a and b).

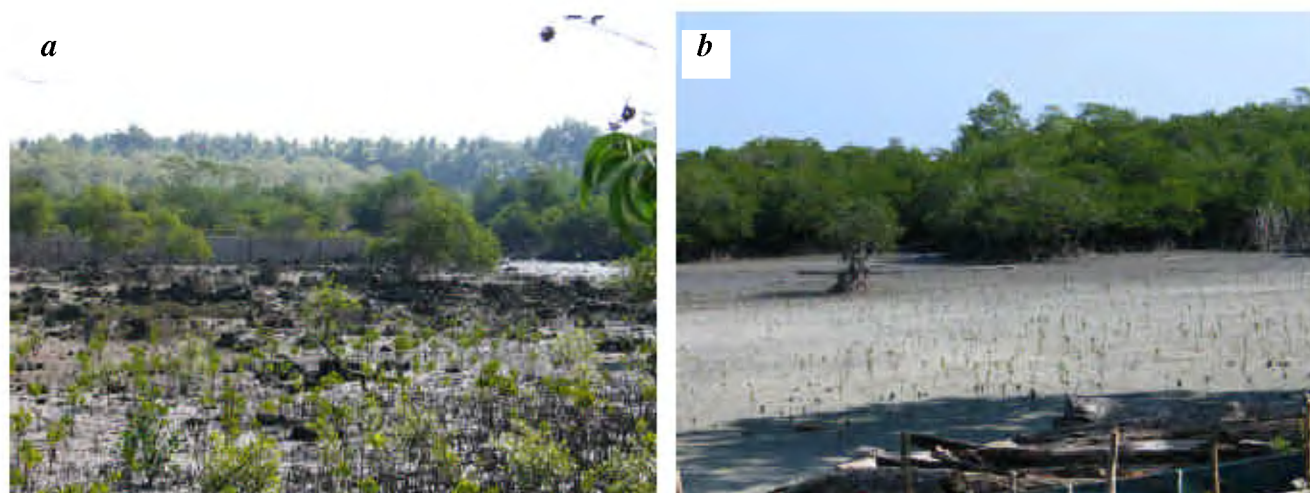


Figure 4. Mangroves remaining exposed even during highest high tide in Middle Andaman (a) and North Andaman (b).

Ecological conditions in a mangrove ecosystem exert pressure on non-mangrove plant species. However, following the disturbance of mangrove ecosystem, as in storm or by human activity, other plant species may encroach and dominate the area. One known opportunistic plant species is the giant fern, *Acrostichum aureum* that inhabits in small patches in dry mangrove areas under normal conditions. But when mangrove trees are felled, it rapidly forms dense growth⁸. This fern possesses large rhizomes, roots and fronds, which can hinder the progress of mangrove seedlings. In the mangrove of Sarawak, besides *A. aureum*, which densely covers the numerous lobster mounds, *Caesalpinia mughis* was observed to spread rapidly in the drier part of the forest⁹. Teas¹⁰ also mentioned the shrubby mangrove *Acanthus* as a plant pest in mangrove clearings. However, according to Watson¹¹, in areas with *Avicennia*, it is recommended that the *Acanthus* be preserved because it holds up the floating *Avicennia* seeds and serves to nurse the seedlings.

It was seen that the water level in Mayabunder and Diglipur, North Andaman has receded by 3–4 ft, which was further confirmed by fishermen and inhabitants of the area. This resulted in the exposure of low-lying areas such as beaches and mudflat.

In North Andaman, mangroves stands of Deshbandhugram, Laxmipur, Milangram and Swarajgram remain exposed and even during the high tides, sea water does not reach the mangrove plants. With the result, the plants have started wilting, and if this condition persists, they will die.

One of the direct impacts of the earthquake which rocked the islands on 26 December 2004, is that the fishermen doing subsistence fishing in mangrove areas are affected due to the changed condition of the mangrove stands. Some fishermen who were operating their boats from the beaches are now forced to relocate themselves. A variety of fish species will also be affected, as mangroves

are the nursery grounds of the marine and estuarine fishes¹². The peak season for fishing in Andamans is November to April. Sample surveys conducted through structured interview schedule in selected landing centres in South Andaman revealed that there is a reduction in the catch in Junglighat and Wandoor. In Wandoor, during the pre-tsunami period, fish landing was of the order of 200 to 270 kg boat⁻¹ day⁻¹ (Nov.–Dec. 2004), while during the post-tsunami period, it has come down to 44 to 55 kg boat⁻¹ day⁻¹. This reduction could be mainly due to loss of fishing boats during tsunami. Immediately after the tsunami, mortality of shellfishes such as prawns and crabs was observed in the vicinity of mangrove areas due to leaching of acid sulphate salts and water quality deterioration.

There is a marked change in the submergence level of coastal areas of A&N Islands due to subduction of land caused by the recent earthquake. This apparently has brought about changes in inundation level due to tidal influence, that is one of the most important factors for proper development and zonation of the mangroves, which has been studied in detail by various authors^{13–15}.

In case of species growing on land flooded during all high tides, *Rhizophora mucronata* will do exceptionally well. Species growing on land flooded by medium high tides are *Avicennia alba*, *A. marina* and *Sonneratia griffithi*. Majority of the mangroves thrive in areas which are flooded during normal high tides and *Rhizophora* seems to be the dominant species. Areas flooded by spring tide only are generally too dry for *Rhizophora* species to survive; they suit well for *Bruguiera gymnorhiza* and *B. cylindrica*. Species growing on land flooded by equinoctial or other exceptional tides are *B. gymnorhiza*, *R. apiculata* and *Xylocarpus granatum*. The above observation is similar to the findings of various authors, who have given detailed scheme of association and zonation pattern of the mangroves of A&N Islands^{3,16,17}. In the context of the present article, it

can be said that many of the mangrove plants may not recover from changes in the salinity regime (especially for the mangrove plants, which have adjusted to the low saline microhabitat). They may also find it difficult to adopt to the permanent change in the submergence level due to subduction of land. Hence we may observe temporal succession in various mangrove zones. *Avicennia* and *Sonneratia* would thrive well in the proximal zone. In the middle zone, where spring tide does not reach the mangrove plants, it has been postulated that *Bruguiera* sp. would replace *Rhizophora* sp., as they are better adapted to the dry condition.

The rise and fall in water level due to tides is a significant factor and it influences salinity, sedimentation, geomorphology and nutrient cycles in the mangrove environment. Mangroves mostly grow in the intertidal zone and each mangrove appears in certain specific tide levels. Sea-level changes, past and present, influence the geomorphic character of a locality and every locality has its own sea-level history resulting from global and eustatic changes of sea level. The sea level causes shifting of mangrove zone seaward or land-ward. The mangrove ecosystem itself gives some evidence of past sea-level changes. Mangroves favour low-wave energy zones as waves cause damage to mangroves¹⁸ and hence they are found in sheltered areas. Therefore, changes in water level brought about due to the subduction effect, will cause changes in the composition of mangrove stands.

While a good number of reports describe post-tsunami effects on mangroves, few attempts have been made to assess the long-term implication by conducting periodic resurvey¹⁹, which is to be done for at least three years to observe the impact on mangrove plants alone. Observations are needed to be taken with respect to soil formation on stripped surfaces, soil erosion, etc. Another important human consideration is the availability of mangrove seedlings, which were reportedly few in the damaged areas²⁰. In the absence of mangrove seedlings for regeneration, herbaceous and shrubby plants will encroach, thus altering the condition of the area. It has been observed the world over that thick patch of mangrove protects people living in the vicinity from natural calamities like tsunami and cyclones. In October 1999, mangrove forests reduced the impact of a 'super cyclone' that struck Orissa on India's east coast, killing at least 10,000 people and making 7.5 million people homeless. Those human settlements located behind the mangrove stands suffered little loss. Similar observations have been made on the 26 December 2004, when the tsunami struck Indonesia, A&N Islands, Sri Lanka and the coastlines of Kerala, Tamil Nadu and Andhra Pradesh²¹. It is therefore in the interest of the people to protect and preserve mangroves, as it is well known that 'mangroves protect those who protect the mangroves'.

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