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V. Santiago-Fandiño
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Contents

Chapter 19
Observations of Natural Recruitment and Human Attempts at Mangrove Rehabilitation After Seismic (Tsunami and Earthquake) Events in Simeulue Island and Singkil Lagoon, Aceh, Indonesia

Ben Brown, Woro Yuniati, Rio Ahmad, and Iona Soulsby

Abstract The December, 2004 tsunami and March 2005 earthquake along the Sunda Megathrust off the Western Coast of Aceh, Sumatra, Indonesia not only resulted in catastrophic losses of life and livelihood, but also changed the very shape of the land and coast. The effects of this rapid change in coastal geomorphology are well expressed in a pair of locations, the remote Island of Simeulue, relatively unknown even in Indonesia before the tsunami, and the district of Singkil, which includes a mainland section as well as the *Banyak* (Many) Islands. Simeulue and Singkil effectively straddle the Sunda Megathrust, yet experienced the cumulative effects of the tsunami and earthquakes differently, with Simeulue Island undergoing seismic uplift while coastal mainland Singkil subsided. After the seismic events, at least 163 separate institutions (government agencies, local and international non-governmental organizations) planned and implemented mangrove rehabilitation activities in Aceh, including over a dozen in Simeulue and Singkil districts. (Brown and Yuniati 2008) Despite a great deal of commitment from such organizations to bringing back mangroves in the affected areas, the majority of the rehabilitation attempts, which mainly relied on hand planting methods, failed to restore mangrove forests. All the while, mangroves were naturally recruiting seismically repositioned intertidal surfaces, and growing well. Near to total mortality was observed in 6 out of 7 planting sites in the two districts, while recruitment rates, stem densities and species diversity in nearby intertidal zones indicated that natural recovery was well underway. When comparing

B. Brown (✉) • W. Yuniati • R. Ahmad
Blue Forests, Ecology Division, Makassar, South Sulawesi, Indonesia
e-mail: seagrassroots@gmail.com

I. Soulsby
Mangrove Action Project – Indonesia, Ecology Division, Bali, Indonesia

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the "success" of natural recovery versus planted sites, we see that practitioners are still faced with significant challenges. This paper makes the case that observation and monitoring of natural regeneration, and calculation of rates of recruitment after a major disturbance event is equally or more important than mangrove planting, from not only ecological but also social and economic points of view.

Keywords Natural revegetation • Post-tsunami • Rehabilitation • Mangrove

19.1 Background: The Impact of Aceh's Seismic Events (Earthquake and Tsunami) on Mangrove Populations

19.1.1 Simeulue District

The Sunda Megathrust occurs along the Western Coast of Sumatra, and extends northwards to Myanmar and Southeast along the Southern coast of Java and Bali, terminating near Australia. It is a volatile region, as it represents the interface between the overriding Eurasian plate and the subducting Indo-Australian plate (Briggs et al. 2006). Numerous large seismic events have occurred along this megathrust, including the eruption of Krakatau, and the 2004 tsunami which claimed over 225,000 lives. (Chlieh et al. 2007).

By reading the corals, much like foresters read tree-rings in temperate latitudes; researchers have been able to tell that major seismic uplift has occurred in 1370, 1600, 1797 and 1833, meaning this occurrence of tectonic emergence is cyclical (Briggs et al. 2006). Subsidence after uplift events occurs in each instance as the Indian Ocean plate sinks and curves under the land mass of Sumatra. This submergence takes somewhere between 75 and 150 years to return the islands to their pre-earthquake position, after which the spring is again loaded and the plate ready for another large earthquake (Briggs et al. 2006).

Prior to the 2004–2005 seismic events, mangrove distribution on Simeulue island occurred nearly entirely along the northern coast of the island, which is protected from the strong waves and currents experienced on the southern coast (Fig. 19.1). As a result of the March 2005 earthquake, the island rose on average 100–150 cm on the Eastern and Western ends, and around 25–75 cm along the central portion (Fig. 19.2). The entire annual tidal range of Simeulue Island, from Lowest Gravitational Tide (LGT) to Highest Gravitational Tide (HGT) is only roughly 78 cm. Approximately 24 species of mangroves have been identified on the island, all of which must exist within that limited tidal range. In fact, the extent of their habitat is narrower still, as they exist only from around Mean Sea Level (MSL) up to HGT, or about 38 cm above LGT up to 78 cm above LGT. The author obtained data points for uplift around the Simueule island, as well as recent tidal data directly from Sieh K (2013, California Institute of Technology (USA), personal communication), enabling the understanding of mangrove re-establishment.

Along the NE and NW coasts of Simeulue, the mangroves as a system were lifted completely out of the intertidal zone in which they must live. A new intertidal zone was

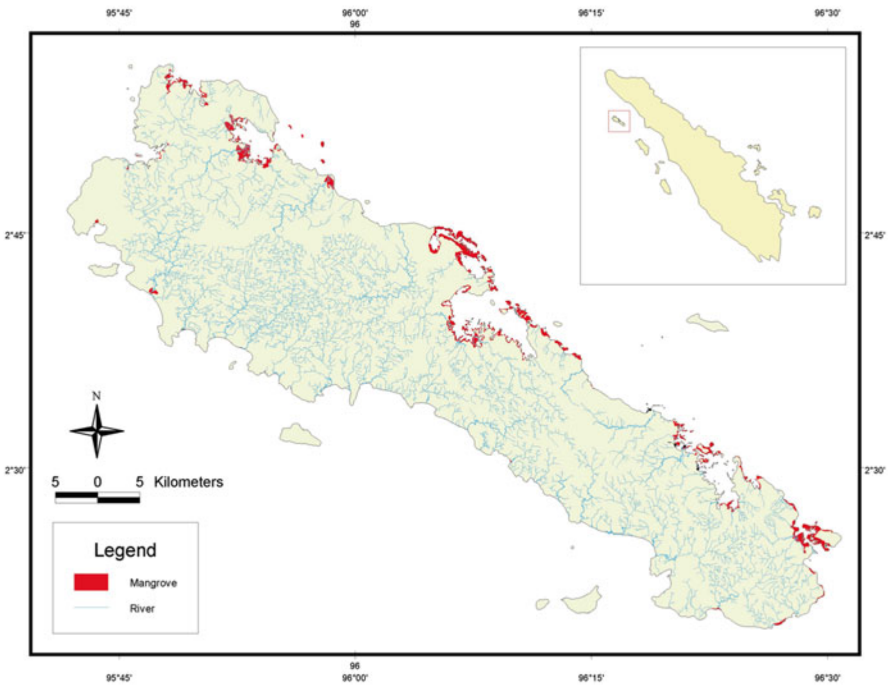

Fig. 19.1 Pretsunami mangroves distribution in Simeulue island (Source: Blue Forests)

formed, in essence, further out to sea. In order for mangrove forests to continue to exist in Eastern and Western Simeulue, their propagules (mangrove fruits and seeds) needed to colonize the new intertidal zone, establish themselves and grow. In NE and NW Simeulue, this process was arduous at first, as the majority of adult trees had been uplifted and began to die. They died both due to desiccation and also due to intense competition with terrestrial vegetation more suited to this new uplifted environment (Fig. 19.3). Only a relatively small number of adult mangrove survived, those which occurred either very low in the tidal profile, near MSL, or those situated directly adjacent to river mouths and tidal creeks. This differed from the North Central coast of Simeulue, in the area known as Teluk Dalam (deep bay). Here a significant number of adult mangroves persisted, as the amount of seismic uplift was less than the tidal range (Fig. 19.3). These adult tress continued to produce and disperse propagules, and, initially, the newly uplifted intertidal zone was colonized at a much higher rate than NE or NW Simeulue.

19.1.2 Singkil District

Whereas Simeulue Island was uplifted between 25 and 150 cm, mainland Singkil experienced seismic subsidence of between 25 and 50 cm. When mangroves are submerged or flooded for an extended period, they succumb to high levels of H_2S in the soil (a by-product of anaerobic respiration). Different species of mangroves,

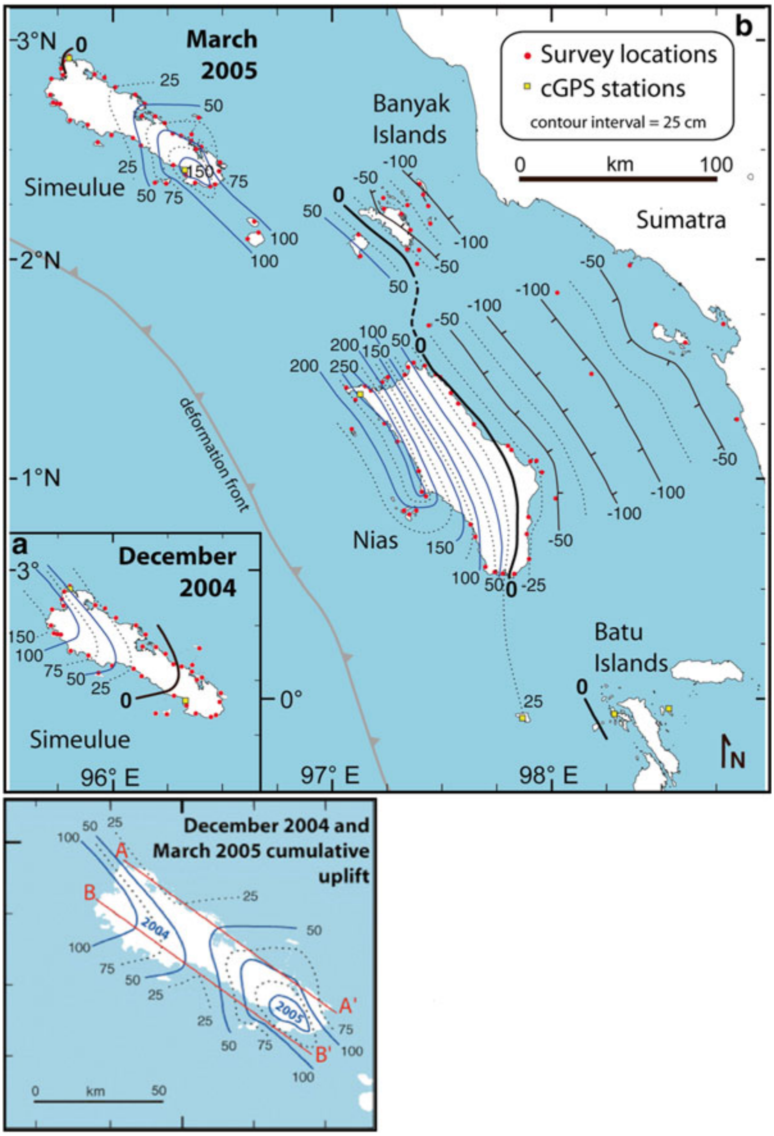

Fig. 19.2 Vertical deformation contour map of Banyak islands after the 2004 and 2005 earthquakes. The zero value (0) line indicates the uplift while the lines on the *right* subsidence (Briggs et al. 2006). The saddle shape uplift in Simeulue island shown on the *right* meant that mangroves on NE and NW coast where lifted entirely out of the intertidal zone, while mangroves in the north central bay (Telum Dalam) largely survived as they were not displaced far from the original intertidal position (Source: Briggs et al. 2006)

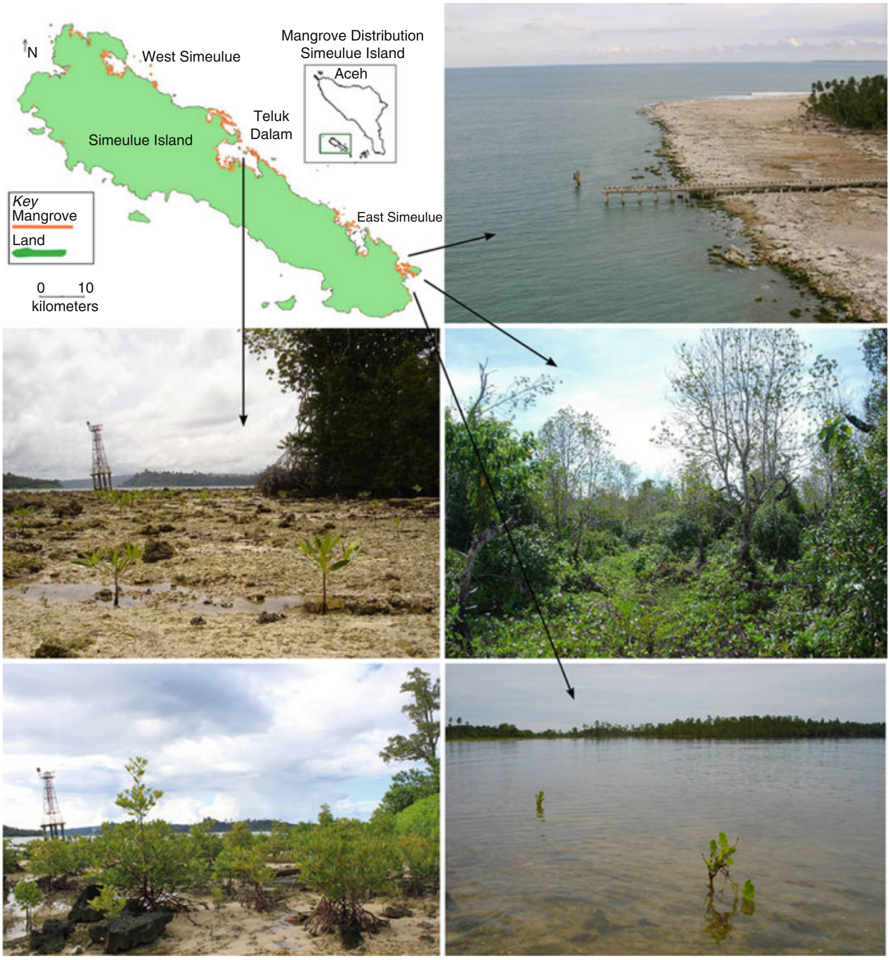

Fig. 19.3 The mangroves in Teluk Dalam, north central Simeulue island have already reached a coverage of 2,268 stems per hectare due to the relative small uplift (*left*). Larger uplift occurred in the Eastern side of the island taking the mangroves away from the original intertidal zone resulting in low level of natural recruitment (*right*) (Source: Blue Forests/author)

have differential tolerances to inundation, a major factor in the apparent zonation of mangroves from based on substrate elevation (from MSL – HGT).

A transect walk through the mangroves on the seaward edge of “Anak Laut” lagoon in Singkil reveals the pattern of mangrove mortality and rejuvenation. *Rhizophora apiculata* is dominant at the lowest elevations adjacent to the open water of the lagoon. As one continues further inland, species dominance changes with substrate elevation in the following pattern;

- Zone 1: *Rhizophora apiculata* (with *Aegiceras corniculatum* in the upper estuary)
- Zone 2: *Brugueira gymnorrhiza* with some *Nypa fruticans*
- Zone 3: *Sonneratia caseolaris*

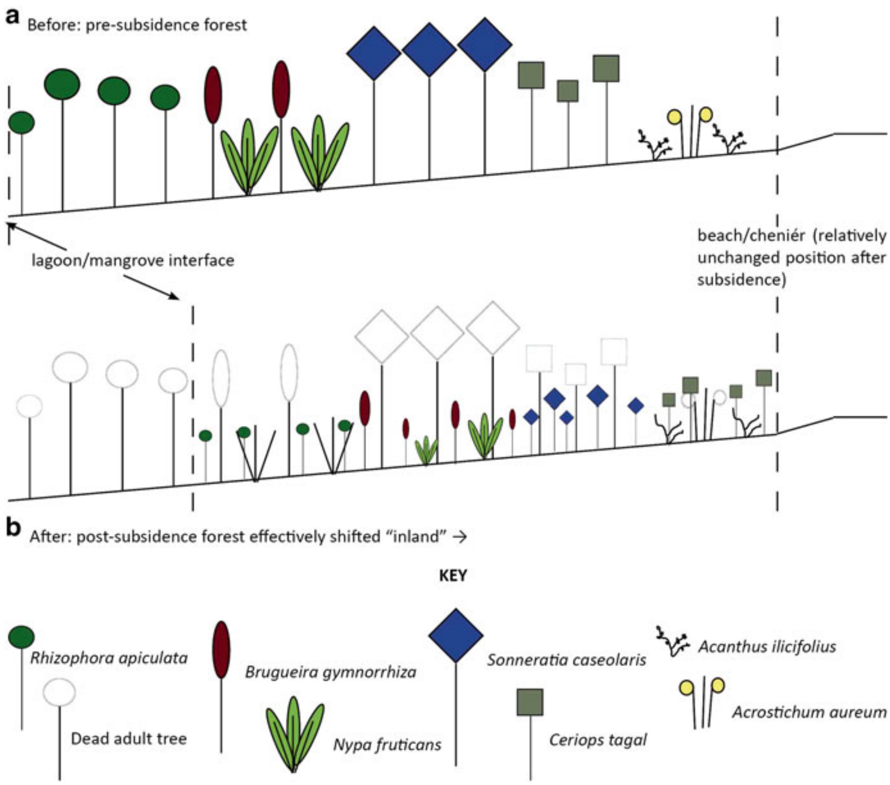

Fig. 19.4 Mangrove forest at Singkil Lagoon before and after subsidence. The original zonation was shifted "inland" after subsidence; the most upland species of mangroves *A. ilicifolius* and *A. aureum* ran out of room to shift inland as the beach/chenier occurred in relatively the same original geographical position before and after subsidence (Source: Blue Forests/author)

- Zone 4: *Ceriops tagal*
- Zone 5: *Acrostichum aureum* and *Acanthus ilicifolius*

After the seismic events and tectonic subsidence, a clear shift took place, with the die off of adult trees, and the establishment of seedlings precisely one zone "upwards."

Adult *Rhizophora apiculata* die off in Zone 1, with adult *Brugueira gymnorrhiza* die off in Zone 2 and establishment of young *R. apiculata* in zone 2 under the dead *B. gymnorrhiza*. This pattern is depicted in Fig. 19.4.

At the highest intertidal elevation, adjacent to the chénier formation that separates the lagoon from oceanic coast, *Acrostichum aureum* and *Acanthus ilicifolius* were forced to retreat onto the submerged sands of the former chénier – which is only a very narrow zone as the chénier itself continues to build due to the action of winds, currents and waves depositing sand. Therefore, these two species were reduced in relative abundance, as their habitat was effectively squeezed.

It must be noted, that this pattern of subsidence and upward migration of mangroves merits further study, as it provides an accelerated analogue of the anticipated effects of sea level rise on mangrove distribution.

19.2 Methods

Ten, 20 m × 5 m vegetation plots were temporarily established shore-left in a random stratified design (Duke 2011). Within each 100 m^2 plot total counts of trees (dbh > 2.5 cm, height > 130 cm, saplings (dbh < 2.5 cm, height > 100 cm) and seedlings (height < 100 cm)) of each species were determined. Girth of each tree was recorded using a tape measure and from this the cross-sectional area, or basal area (BA), was calculated to give an indication of growth and dominance. Tree height was recorded using an extendable height stick. Height of the first ten saplings and seedlings encountered were recorded.

A pair of sits (Teluk Dalam – Mercu Suar and Teupah Selatan) were monitored twice at a 12 month interval. The relationship between average stem densities over time for these two sites were examined with correlation analyses. Changes in density between pre-rehabilitation survey and most current survey data per site were analyzed with paired student T-tests using months since rehabilitation and average densities as group factors at 95 % confidence levels. The remaining four sites were only measured once, and a rate of recruitment was calculated simply by dividing the average stem density by the 7 years since the most recent major seismic disturbance (March 2005).

In all, six sites were measured, four of which had not experienced any degree of mangrove planting and two of which had been previously planted as part of the earlier rehabilitation attempts:

Never planted

1. Teluk Dalam-Mercu Suar (TDMS)
2. Teupah Selatan (TS)
3. Singkil Lagoon 1 (SL1)
4. Singkil Lagoon 3 (SL3)

Previously planted

5. Teluk Dalam-Sambay (TDS)
6. Singkil Lagoon 2 (SL 2)

To better understand stakeholder perspectives, non-formal interviews, formal interviews and focus group discussions were conducted with 200 villagers in partner villages in Simeulue Island and Singkil, as well as government agents from District Level Forestry Department, and Environmental Agency. Data was not analyzed, but anecdotes are used below.

19.3 Reflection on Human-Assisted Mangrove Rehabilitation in Changing Intertidal Zones (from Social – Economic and Environmental Perspectives)

It was reported that the 2004 tsunami in Aceh destroyed 32,000 ha of mangroves along the Aceh coast (Department of Fisheries and Oceans, 2005; and NAD Province Department of Forestry, 2005 as cited in Purwanto 2008). In response to this loss, 164 institutions, both government and non-governmental, (including only those registered with the Nanggroe Aceh Darussalam Bureau of Reconstruction and Rehabilitation), engaged in mangrove rehabilitation in the affected areas (Brown and Yuniati 2008). A pair of these mangrove planting projects is discussed below.

The Australian Red Cross (ARC) initiated the planting of 60,000 mangrove seedlings at five sites on the North Coast of Simeulue Island in 2006. Project monitoring 1 year later, in 2007 indicated total mortality at three sites, 25 % survivorship at a 4th site and 70 % survivorship at the 5th site (ARC Simeulue Office – project report, 2007). At this point, ARC contacted Mangrove Action Project – Indonesia, who was contracted to undertake a rapid assessment leading the recommendation that an Ecological Mangrove Rehabilitation (EMR) training be initiated with eight villages who were involved in planting the five sites. The training occurred in 2007, participated in by 30 women and men from the 8 villages. Evaluations of the training revealed that the majority of community members wished to attempt follow-up activities to rehabilitate mangroves in replanted sites, using techniques of propagule distribution and some hydrological repair; however, the 3 year ARC project came to an end, and no further action was taken by ARC, MAP or the local communities.

Between 2010 and 2013 a project under the USAID CADRE program[1] engaged Lutheran World Relief to continue mangrove rehabilitation and conservation activities in five villages on the North Coast of Simeulue Island, and five villages around Singkil Lagoon. In the project plan, mangrove rehabilitation sites were to be chosen after social (land tenure, stakeholder support) and ecological feasibility studies were undertaken. However, in practice, project managers pre-selected all ten villages before the feasibility study was conducted. In Simeulue, the five villages selected were all located in Teluk Dalam, where natural recruitment was already estimated as “recovering.”

It was determined to take baseline surveys of natural recruitment in order to revise recommendations of potential rehabilitation sites. In both Simeulue and Singkil Lagoon, baseline surveys would reveal that natural recovery rates were already higher than the project’s success criteria (see Sects. 4.1 and 4.2 below), and that no genuine mangrove rehabilitation sites existed at selected project locations. A genuine rehabilitation site was considered a site where natural recruitment, without human intervention, would not be sufficient to effectively restore mangrove populations. In search for viable rehabilitation sites (so that project targets of 400 ha of mangrove rehabilitation could be met) it was hypothesized that newly uplifted intertidal areas in Eastern Simeulue would not be recruiting at sufficient rates to repopulate mangroves in the near-term, and that human intervention was needed to

[1] Increasing Coastal Resiliency & Climate Change Mitigation through Sustainable Mangrove Management in Sumatra.

expedite the process before permanent alterations to the landscape (infrastructure development) were made. A baseline survey was also called for, to determine natural recruitment rates in Eastern Simeulue at an area known as Teupah Selatan.

In terms of government policy, mangrove rehabilitation in Indonesia is planned and budgeted for annually, in each province and coastal district. Processes include site selection, community awareness building, nursery development and planting at 1 m – spacings (BPDAS and South Sulawesi 2013). All activities are to take place within a single year. Monitoring occurs within 3 months after planting. Two such government planting practices were observed in Simeulue and Singkil during the timing of the ARC and CADRE projects. A 2005 forestry department planting event in Linggi Village, Simeulue promoted 100 ha of direct planting. One year after the event, only 0.5 ha of planted mangroves are evident (Fig. 19.5). Government officials

Fig. 19.5 Mangrove planting at Linggi Village, Simeulue. Out of 100 ha planted in 2005 only 1 ha of seedlings were evident in 2006 (*upper left*). Wooden stakes are the only remnant of around five additional hectares of wrongly planted *R. appiculata* at the landward edge of the intertidal zone were the species cannot grow (*middle left*). In the *bottom lower* picture thriving natural recruits of *S. caseolaris* are found amongst a graveyard of dead planted *R. apiculata*. Pioneers species such as *S. caseolaris* should be consider for human assisted propagule distribution, to colonize appropriate substrate as the first step in the rehabilitation of disturbed mangrove forest. In 2011 only 0.5 of the original 100 ha remained alive (*top right*) (Source: Blue Forests/author)

interviewed sited poor planting practices, poor species selection, poor condition of seedlings and herbivory by water buffalo as reasons for failure. Herbivory fails to explain the living 0.5 ha or thriving natural recruits at the site.

A similar planting took place in Singkil Lagoon in 2011. This planting took place on micro-deltas formed at the Southern end of the lagoon, and at the time at appropriate substrate elevations. However, rapid sedimentation took place over the course of the following year, and planted *Rhizophora apiculata* were 100 % "replaced" with naturally recruiting *Casuarina* sp., a common beachfront pioneer species.

Economically indeed, there must be a better way to use money earmarked for mangrove planting. It is reported that Ecological Mangrove Rehabilitation costs on average $600–1,500 per hectare when implemented in Indonesia and has a high success rate (Lewis and Brown 2014). In many cases, the benefit of such as process is simply to recommend that a site not be restored due to social or ecological reasons. Post-tsunami, villagers from Jaring Halus in North Sumatra provided over 1,000,000 seedlings per year (Fig. 19.6) for 3 years out of their 42 ha village forest, packed and shipped overland to Aceh to an unknown fate (Brown and Yuniati 2008).

Some local NGO's and members of communities have expressed their doubts about the effectiveness of mangrove planting as the trees are able to come back on their own. An example was the case of the Banyak islands where many mangroves died after the Nias earthquake but started to grow back naturally (Bpk. Zukifli, 2013, Department of Forestry. Singkil, personal communication).

Fig. 19.6 One batch of the one million seedlings shipped annually from Jarig Halus to Aceh (Source: Mangrove Action Project – Indonesia/author)

19.4 Observed Natural Recruitment

19.4.1 Simeulue

Of all the sites measured, the previously un-planted sites at Teluk Dalam exhibited the highest stem density (2,859 stems/ha), average annual rate of recruitment (408.4 plants/year), and total species diversity (12). Teupah Selatan, an un-planted site in Eastern Simeulue hypothesized as "in need of human assisted propagule distribution" exhibited lower average stem density (2,117 stems/ha), average annual rate of recruitment (302.5 plants/year), and total species diversity (7), exceeding expected results. With a rate of recruitment expected to add 900 plants/ha over 3 years, this site was re-evaluated as "not requiring human assistance for rehabilitation," as natural recruitment would exceed CADRE project targets (1,250–2,500 seedlings/ha after 3 years of intervention).

The final site measured in Simeulue was an ex-planting site at Teluk Dalam, Sambay. This site was planted twice since the tsunami, both with qualitatively high mortality. At the time of sampling, it was difficult for the team to distinguish planted material from natural recruits for *Rhizophora apiculata*, yet the other six species present were all natural recruits as they were not planted by either planting project. The overall stem density at the time of sampling was 467 stems/ha with a recruitment rate over 7 years of 66.7 comprised of seven species. Results are summarized in Table 19.1.

19.4.2 Singkil

Mangrove stem densities, recruitment rates and species diversity were also surveyed at a trio of sites in Singkil Lagoon; SL1, SL2 and SL3.

SL 1 is located near a newly cut channel between the sea and the lagoon and exhibited a mean density of Mean density of 2,980 plants per hectare. This site exhibited the pattern of a shift of species to higher elevations after seismic subsidence described in Sect. 2.2. SL2, includes areas previously planted, and then succeeded by *Casuarina* due to rapid sedimentation. The mangrove stem density at this site was 160 plants/ha. SL3 was not formerly mangrove forest, and has been colonized by *Acrostichum aureum* after subsidence, indicating this site is now at the upper intertidal limit for mangrove distribution. The local community with support from the CADRE project has planned an intervention for this area, razing the *Acrostichum aureum*, digging in tidal channels to facilitate water exchange with the lagoon, and planting woody mangrove species. Findings for all three sites at Singkil Lagoon are also summarized in Table 19.1.

Table 19.1 Stem density and species diversity for four un-planted and two planted sites in Simeulue and Singkil Districts

	Area	Site	Size (ha)	Stem density	Statistics	Species present	No. & size of plots
Simeulue island							
1	TelukDalam	MercuSuar	14	0.29/m^2 2,859/ha	Standard deviation = 0.22 Variance = 0.05	Total = 9 (12) *A. aureum* *B. gymnorrhiza* *C. tagal* *L. littorea* *P. acidula* *R. apiculata* *R. mucronata* *S. alba* *X. granatum* Observed at site but not sampled: *A. ilicifolius* *A. speciosum* *B. sexangula*	n = 13 100 m^2 (5 m × 20 m)
2	TelukDalam	Sambay	1.65	0.047/m^2 467/ha	Standard deviation = 0.039 Variance = 0.002	Total = 4 *B. gymnorrhiza* *C. tagal* *R. apiculata* *R. mucronata*	n = 6 100 m^2 (5 m × 20 m)
3	Teupah	Teupah Selatan	99.99	0.212/m^2 2,117.39/ha	Standard deviation = 0.18 Variance = 0.03	Total = 7 *A. aureum* *B. gymnorrhiza* *C. tagal* *L. littorea* *N. fruticans* *R. apiculata* *R. mucronata*	n = 23 100 m^2 (5 m × 20 m)

Singkil							
4	AnakLaut Lagoon	SL1	8.10	$0.30/m^2$ 2,980/ha	Standard deviation = 0.10 Variance = 0.01	Total = 4 *B. gymnorrhiza* *R. apiculata* *S. caseolaris* *A. aureum*	n = 5 100 m^2 (5 m × 20 m)
5	AnakLaut Lagoon	SL2	6.06	$0.02/m^2$ 160/ha	Standard deviation = 0.02 Variance = 0.0002	Total = 4 *L. littorea* *R. apiculata* *S. caseolaris* *A. aureum*	n = 5 100 m^2 (5 m × 20 m)
6	AnakLaut Lagoon	SL3	6.12	$0.11/m^2$ 1,080/ha	Standard deviation = 0.04 Variance = 0.0013	Total = 3 *R. apiculata* *S. caseolaris* *A. aureum*	n = 5 100 m^2 (5 m × 20 m)

Source: MAP; Indonesia/author

19.5 Discussion

Improper selection of mangrove rehabilitation sites took place frequently after the seismic displacement of the intertidal zone. Even where experienced mangrove rehabilitation practitioners were enlisted, the mechanisms of post-disaster project planning and project management superseded careful assessment.

Although this paper is largely anecdotal, one single monitoring event's worth of evidence of natural recovery versus planting success was undertaken, however it was not performed as an academic study, but rather in the context of disaster relief programming. What is notable, is that natural recovery, in some sites, had already exceeded success criteria of the rehabilitation project. Stem densities per hectare were higher than project targets in sites chosen for rehabilitation at both Simeulue and Singkil. Species diversity was certainly higher due to natural recruitment than planting alone, but should be described as a percentage of known local species diversity present in nearby reference forests. Rate of recruitment was calculated simply by dividing species density over time since disturbance, but should be tracked through several monitoring events to develop a more realistic linear progression. A pair of assessment methods are given in the conclusions to assist project managers in more deliberate planning.

In Teluk Dalam, Simeulue, natural recruitment was expected, as seismic uplift was less than the tidal range, and significant numbers of adult trees were noted not only to have survived the disturbance event, but to have remained fecund. In Eastern Simeulue, however, it was hypothesized that stem density would be significantly lower and natural recruitment rates significantly slower than Teluk Dalam, as many adult mangrove forests were uplifted entirely out of the zone of tidal influence. Enough trees, however, remained both alive and fecund, and stem densities of greater than 2,000 stems per hectare were encountered.

In Singkil Lagoon, which underwent seismic subsidence, adult trees died, but enough remained alive and fecund in order to colonize newly attenuated intertidal surfaces. Essentially, mangroves were noted to have shifted "upwards" along with the tidal frame. Mangroves planted in the micro-deltas formed at the far end of the lagoon grew initially but died off within a year due to rapid sedimentation, evidenced by colonization of *Casuarina*. Caution needs to be taken at all times when attempting to plant mangroves, so that their habitat requirements are met, but an extra degree of caution is needed in the case where a coastline is resettling after a period of disturbance. Such is the case in Aceh, where the subduction of tectonic plates begins anew, and displaced substrates are in a state of flux, due to geomorphological deformation, changing patterns of sedimentation (Fig. 19.7), compaction and other factors.

Fig. 19.7 Natural mangrove recruits *B. gymnorhizza* buried alive by rapidly changing sedimentation patterns (Source: Blue Forests/author)

19.6 Conclusion

It is clear that increased attention is paid to use of proper assessment methods when selecting mangrove rehabilitation sites. Examples of appropriate assessment tools include; (a) assessment chapters in *Ecological Mangrove Rehabilitation – A Practitioner's Manual* (Lewis and Brown 2014), and (b) *Tsunami Damage to Terrestrial Coastal Ecosystems Common Guidelines and Methodology for Rapid Field Assessment* (IUCN 2005).

In a post-disaster scenario, rapid assessments methods are required, but for obvious humanitarian reasons, rehabilitation planning should take place only after stabilization and resolution of major humanitarian issues (trauma, water, food and shelter). In cases where drastic geomorphological change has taken place, a long period of observation may be necessary before action taking. Resource intensive activities, such as nursery development and mangrove planting should not be considered in an initial period, if at all. Human assistance in collecting and distributing propagules to promote natural regeneration should be considered, coupled with careful monitoring of human assisted versus natural recruitment (Fig. 19.8).

Where mangrove planting projects have been attempted by governments, NGO's, and communities, without rigorous methodologies, failure can lead to

Fig. 19.8 Periodic human assisted propagule distribution to reestablish mangroves on appropriate intertidal surfaces and monitoring in collaboration with local communities (Source: Blue Forests/ author)

apathy amongst local stakeholders, where concerns over maintenance of annual government budgets, or short-term cash-for-work supersedes genuine intentions to restore mangroves as a vital coastal ecosystem. Economically, funds for repeated planting projects, without monitoring and feedback mechanisms can result in large-scale wastes of public and private financial resources and the detriment of the rehabilitation of mangroves in tsunami hit areas.

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