Protective function of natural coastal ecosystems against the impact of tsunami: A case study from Medilla to Godawaya in South-eastern Sri Lanka

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Abstract: - Tsunami-related environmental impacts on the coastal ecosystems from Medilla to Godawaya (27 km) in south-eastern coastline of Sri Lanka were documented through a rapid assessment methodology, with the objective of gathering scientific evidence on whether coastal natural ecosystems have contributed to reduce the damage on more interior landscapes. The methodology included the study of qualitative ecological parameters and quantitative analysis of structural damage to trees and modification of ground features in sites just behind the narrow strip of land facing the sea. Once the beach front features were correlated with above damage scores, it was observed that mature and intact sand dunes have functioned as an effective barrier against the tsunami waves, thereby protecting inland ecosystems and human settlements. Intact and broad stands of mangrove and *Pandanus* vegetation have also served as a frontline defence by absorbing the wave energy of Tsunami. Coastal wetlands, including mangrove swamps, salt marshes, broad estuaries and lagoons also have diffused the destructive power of sea-water and sediments brought in by the tsunami waves, thereby protecting managed landscapes such as paddy fields and settlements. In addition, it was noted that coral reefs, rocky beaches and sandstone reefs have reduced the energy of incoming waves. Moreover, it was observed that tsunami waves have penetrated inland with a greater force in areas where natural sand dunes have been exploited and/or converted into managed landscapes such as Coconut plantations and home gardens. Areas, where nearby coral reefs have mined or destroyed by previous bottom set netting, were also considerably damaged by tsunami waves. Hence, the presence of healthy natural ecosystem components in coastal belt assist in minimizing Tsunami impacts considerably.

Key-Words: - Protective function, Tsunami, Coastal ecosystems, Sand dunes, Mangroves, Sri Lanka.

1. Introduction

In the aftermath of the Indian Ocean tsunami (26th December 2004), which killed over a quarter million people and left millions homeless, experts and the media wondered how many lives might have been saved if only we had not destroyed our mangrove forests [1]. The scale of the Boxing Day tsunami was almost unprecedented. However, areas with coastal tree vegetation were markedly less damaged than areas without [2].

The great human tragedy resulted in some devastating impacts on the study area of the present survey, and paved an opportunity to understand the role of natural coastal ecosystems against those massive tidal waves.

According to Dahdouh-Guebas et al. (2005), whether or not mangroves and other coastal ecosystems function as buffers against tsunamis is a subject, which needs in-depth research, the importance of which has been neglected or underestimated before the recent killer tsunami struck. Surprisingly there is little data available to test that hypothesis.

Therefore, the present paper attempts to present some qualitative and quantitative evidence to show the protective function of natural coastal ecosystems against the impact of the Boxing Day tsunami, taking the coastline from Medilla to Godawaya in South-eastern Sri Lanka as a case study.

1.1 Objectives of the study

The main objective of this rapid assessment was to gather scientific evidence on the capability of coastal natural ecosystems in protecting the interior landscapes during the recent tsunami event. This study would also shed light on addressing environmental concerns of current redevelopment plans for the coastal zone of Sri Lanka. It is also expected to present the rapid assessment methodology used for the study, which could be used in assessing the impacts of other natural disasters with relevant modifications

2 Methodology

2.1 Study area

The coastline from Medilla to Godawaya constitute a 27 km section of the south-eastern coastline of Sri Lanka, located in the Hambanthota District. The area contains an array of coastal terrestrial and wetland habitats, including managed landscapes. The main natural coastal habitat types include mangrove, sand dunes, scrubland, salt marshes, reed beds, and maritime grasslands, while the managed landscapes include rice fields and home gardens. The coastal wetlands in the area includes the Rekawa lagoon (250 ha), the interconnected Kalametiya (606 ha) and the Lunama (192 ha) lagoons, the narrowly branched Kahanda-modara estuary (<100ha) and the Walawe estuary [3,4,5]. An assessment of biodiversity conducted by IUCN Sri Lanka (2004) enabled to document a total of 287 plant species belonging to 65 families from the above inland habitat types in the study area. The fauna documented include a total of 328 species of vertebrates, of which 14 species (4%) are endemic, while 27 species (8%) are nationally threatened. The stretch of beach in this area includes important nesting sites of all five species of globally threatened marine turtles that lay eggs in Sri Lankan coasts.

The beaches of the study area are composed predominantly of a sandy coastline, while sandy beaches are interspersed by several rocky headlands often supporting coral reefs, river and lagoon estuaries and coastal sandstone beach-reefs. The beaches are steep, often rising 4-7m from the mean waterline, and are exposed to strong seas. There are significant dune formations as well [3,6]

Observations were taken in different locations using a rapid assessment approach in line with Quota sampling [7], with appropriate modifications to suit the field conditions. The study area (Figure.1), was divided into four manageable survey segments, in the following manner:

Segment 1:Rekawa(Medilla to Beliwinnegoda)
Segment 2: Rekawa to Kalametiya (Oruwella fishery harbour to Gurupokuna fishery harbour)
Segment 3: Kalametiya & Lunama
Segment 4: Ussangoda to Godawaya (Ussangoda fishery harbour to Walawe river estuary)

The above stretches constitute four broader bays found within the study area. Each segment was surveyed and qualitative observations were made to document the nature of tsunami impact and the protective function of natural landscapes against it. Quantitative data were gathered on structural ecological damage in 13 selected plots.

2.2. Study of qualitative environmental parameters

Field observations were recorded in a qualitative manner for the entire beach stretch from Godawaya to Medilla.

Following features of the coastline were documented qualitatively as they could be assisted in the interpretation of quantitative data.

- Coastal land features and locations.
- Beach characteristics and beach profile.
- Stability and condition of the beach and/or sand dune.
- Type and condition of the beach vegetation.
- Type and condition of the vegetation/land use type immediately interior to the beach.
- The density of human settlements and their proximity to coastline.
- Structural damages caused by tsunami to coastal landscape and vegetation.
- The distance to which the tsunami water has penetrated inland and the distance to which the tsunami currents have caused major damage to vegetation and/or property.
- Pre-tsunami human interferences (coral mining, sand mining, beach front constructions, fisheries, tourism, etc.).

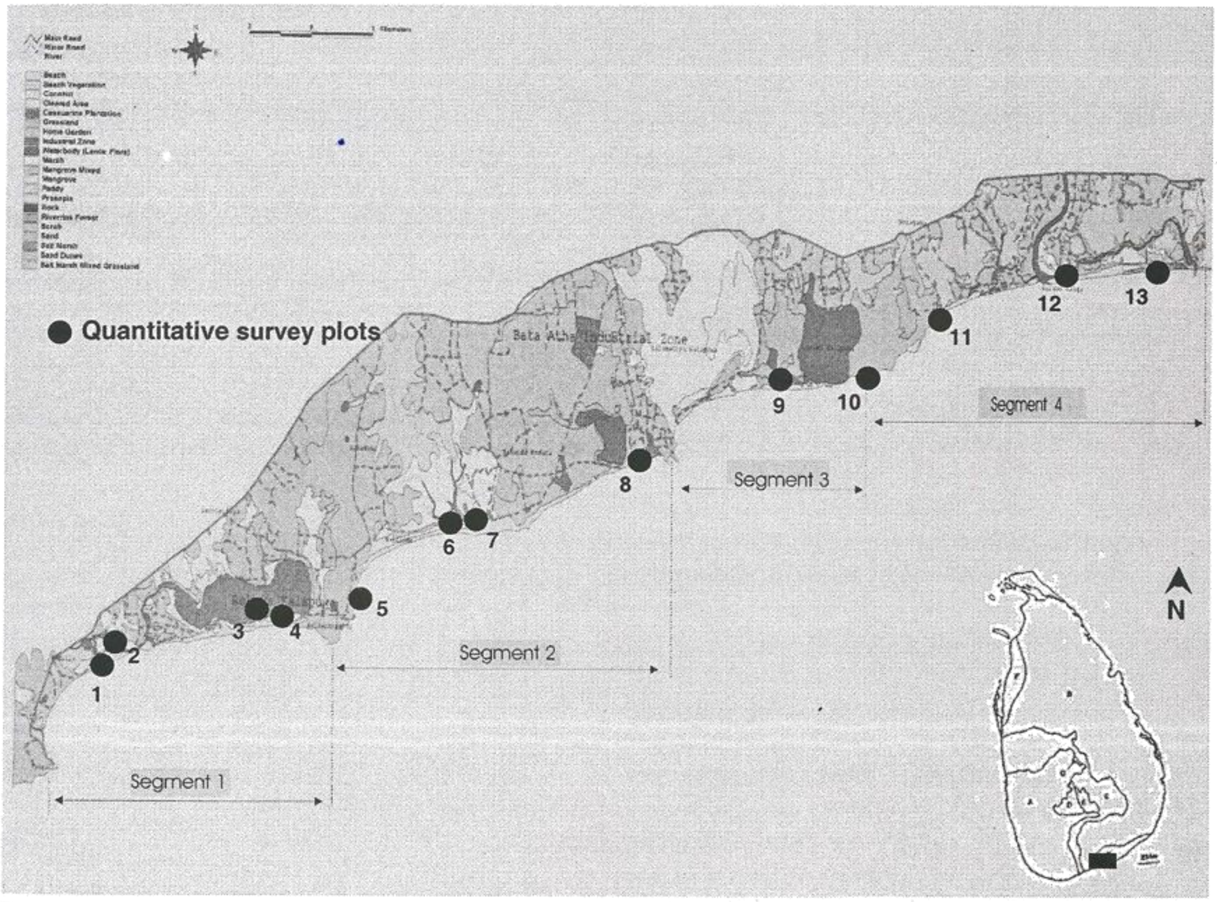

Figure 1. Map of the study area showing four coastal segments and plots surveyed

2.3. Quantitative study of structural ecological damage

Detailed ecological investigations were made in 13 selected sites within the four study segments. The specific sites (within 100m from the coastline) were selected in a manner that captures the diversity of beach/coastal features (including habitats and human modifications). The structural ecological damage of 13 selected sampling plots was studied quantitatively, where a site-specific impact score was assigned for tree damage and alteration of ground features using a situation specific adaptation of a rapid analytical technique developed by FAO [8]. The composite impact score for the inland plots (within the 100 m zone from the coastline) for each site was analysed and interpreted in relation to their seaward environmental features, and their level of modification by human activities (Table 1.).

Table 1. Sites selected for quantitative analysis of structural damage (from south-west to south-east), and corresponding features of seaward/beachfront environment and their level of modification by human activities.

		Seaward environemnt	
Plot No.	**Location**	**Habitat / beach front features**	**Degree of modification (pre tsunami)**
1	Medilla modara	Artificial canal system and outlet, low stature sandy beach, beach front constructions (hotels etc), original beach scrub cleared	High
2	Medilla mangrove	Intact mangrove stands	Low
3	Rekawa mangrove	>5m tall broad sand dune with a mature coconut plantation established without exploiting the dune. The dune borders the Rekawa lagoon & mangrove.	Low
4	Rekawa coconut land	Moderate sand dune (>2m in height with a moderate slope) and sandy beach.	Moderate
5	Oruwella	Narrow bay and low stature narrow sandy beach, and severely exploited near-shore coral reef	High
6	Wellaodae	Low stature sandy beach (low in height, almost flat) with coconut plantation and constructions (hotels etc)	High
7	Kahandamodara	Intact mangrove stands spread across lagoon branches	Low
8	Kunukalliya	>5m tall moderately mature sand dune with scrubland.	Low
9	Lunama mangrove	>5m tall moderately mature and broad sand dune with scrubland vegetation	Low
10	Lunama scrubland	Moderate stature sandy beach (1-2m tall, moderate slope) and immature sand dune	Low
11	Ussangoda	Low stature sandy beach degraded and cleared scrubland.	High
12	Modaragama	2-3m tall immature sand dune and beach, Walawe river, artificial canal	High
13	Godawaya	Casuarina plantation on a 2-3m tall sand dune	Moderate

2.3.1. Assessment of structural damage to trees

The degree of structural damages to trees having stems above 20cm girth at breast height were recorded in a continuous 2m belt transect in the selected tree dominated habitat. Altogether 50 stems per plot were enumerated. The tree damage was estimated by assigning the following scores, based on leaning of stems, stem damage and canopy damage caused by the tsunami waves:

Level of stem leaning:
Score-1: No leaning, stem is upright or showing natural leaning with or without tsunami influence.
Score-2: Leaning 60-45 degrees with clear evidence of damage due to tsunami waves.
Score-3: Leaning 45-30 degrees with clear evidence of damage due to tsunami waves.
Score-4: Fallen stem with clear evidence of damage due to tsunami waves.

Level of stem damage (stem below 50% of the total height of the tree)
Score-1: No damage with or without tsunami influence.
Score-2: Slightly damaged with clear evidence of damage due to tsunami waves.
Score-3: Severely damaged with clear evidence of damage due to tsunami waves, but the trees are not dead or separated from the main stem.
Score-4: Uprooted and fallen, dead stem or stump remains with clear evidence of damage due to tsunami waves.

Level of canopy damage (stem/branches above 50% of the total height of the tree)
Score-1: No damage with or without tsunami influence.
Score-2: Few branches damaged with clear evidence of damage due to tsunami waves.
Score-3: More branches damaged with clear evidence of damage due to tsunami waves.
Score-4: No canopy or dead canopy with clear evidence of damage due to tsunami waves.

2.3.2. Assessment of alteration of ground features

The selected plots were traversed in a series of random walk transects, to document the alteration of ground features as a result of tsunami waves. This was done while walking along a transect for 50 paces (steps), and recording the ground cover type right below a marked point at the tip of shoe. Each of the 13 sites were covered by ten transects of 50 paces having a total of 250 sampling points (25 points per transect). Ground cover type of the observation point was noted and identified based on visual observations whether it is a result of Tsunami event. Some examples for ground cover types brought about by tsunami event were; transported organic debris, transported sand/mud, exposed roots, transported building debris, eroded sand/mud, fallen logs/tree branches and transported rock/coral/shells.

The proportion of different ground cover types in each site (n=250) was used in interpretation of impacts. The ratio of total number of tsunami-related ground cover types in relation to 250 observations was converted into a scale of 1-4 (by multiplying with 4), where a score of 0 referred to no impact, while a score of 4 meant the most intense impact on ground features.

2.3.3. Composite score of tsunami damage

All above scores tabulated for tree damage and ground cover features were averaged to get a composite score of tsunami damage. Mean composite plot scores were calculated by averaging the total of scores recorded for a particular site. Final score for the level of damage was interpreted in the following manner:
Score 1 or <1: No or very low impact
Score 1+ to 2: Low Impact
Score 2+ to 3: High impact
Score 3+ to 4: Severe impact

2.4. Limitations of the study

Lack of data on coastal bathymetry, and physical information on the tsunami waves (i.e., strength of waves, their direction etc.) that hit the study area posed a limitation in interpreting tsunami impacts in relation to pre-tsunami human modifications to coastal habitats. Lack of access to pre and post-tsunami satellite images and/or aerial photographs of the area was also a constraint in analysing the impacts. In addition, there can be an element of subjectivity inherently associated with rapid assessments, which have been minimised by ensuring the consistency of the method and collection of data by the same field researchers in all sites within the study area.

3. Results and Discussion

3.1. Qualitative observations on tsunami damage on coastal habitats in the study area

The damage to the coastal stretch in the study area was patchy in general. As the area consists of four broader bay segments, it was observed that the tsunami had impacted mainly on the western flanks of each bay i.e. Medilla to Tangalle, Oruwella fishery harbour area, Kalametiya fishery harbour area, and Pattiyawaraya to Ussangoda fishery harbour area. Tsunami waves have entered inland with a higher force in narrow bay areas possibly with trenches in the sea bottom topography (e.g. Oruwella), and a funnelling effect was evident in areas with narrow tidal inlets, river mouths and artificial canals made by people to drain or connect coastal water bodies to the sea.

Qualitative observations were made on the tsunami-related impacts on the coastal habitats in the study area. The gentle sea-shore vegetation consisting of creeping plants such as *Spinifex littoreus* and *Ipomoea pes-caprae* and erect species such as *Pandanus odoratissimus* have been affected up to more than 50% of the original cover. The sandy beaches and seaward flanks of sand dunes have been eroded, resulting in reduction of beach width in certain locations such as Oruwella. The natural hydrological conditions in salt marshes and maritime grasslands have been affected due to large volumes of sand and marine sludge being deposited on them, which in turn has destroyed the short vegetation of these ecosystems in Rekawa and Welipatanwila.

In most of the mangrove stands in the survey area, fringes near the water edge were structurally damaged, absorbing most of the wave energy. But mangroves found more inland, were well protected by those frontline fringes, as described by Dahdouh-Guebas et al. (2005) in their study on tsunami impact on mangroves. *Ceriops tagal* Dominant mangrove community in Medilla, *Avicennia officinalis* dominant community in Kapuhenwala, as well as mixed communities in Welipatanwila and Wellaodae were among the most affected mangrove stands within the study area. The ground features of mangroves have also been changed, due to deposition of sand, marine sludge and other debris.

The vegetation in home gardens affected by the tsunami waves were observed in Wanduruppa and Oruwella area, either being uprooted, or dying off due to high saline conditions in the soil. Low-lying paddy fields have been destroyed by saline water and marine sludge depositions. Other wetlands such as lagoons (i.e., Kalametiya and Rekawa) and estuaries (Walawe, Kahanda-modara) have undergone changes in relation to increases in salinity, and deposition of sand, mud and other debris, including non-biodegradable material.

3.2. Site specific cases of tsunami damage and protective role of coastal ecosystems

In the study plot 1 (Medilla modara), where mangrove vegetation is being disturbed by human activities, a severe damage with an average impact score of 3.6 was observed, resulted from the funnelling of sea water through the artificial canal made to drain water from Rekawa lagoon.

In study plot 2 (Medilla mangrove), the strip of mangrove vegetation located about 100m from the beach front, which is shielded by a thick and broad mangrove stand on the seaward environment, showed low damage, with an average impact score of 1.4. This highlights the buffering effect of front line mangroves, which has minimized the damage to interior vegetation.

No damage was observed to the study plot 3 (Rekawa mangrove), which is a mangrove stand, well shielded from the wave by being located behind the elevated dune. In the study plot 4 (Rekawa coconut land) on the elevated dune, the damage was low with an average impact score of 1.7.

In study plot 5 (near Oruwella fishery harbour), damage to vegetation was severe, as evident from the average impact score of 3.9. The near-shore fringing coral reef, located about 50m away from the beach in this narrow bay is in a highly degraded status due to prolonged mining and bottom set netting.

The function of dunes and mangrove as a frontline buffer against tsunami waves was evident in the damage analysis in study plots 6 (Wellaodae) and 7 (near Kahanda-modara estuary). The impact on mangrove vegetation immediately behind the low statue beach at Wellaode was severe (average impact score of 3.4). However, the strip of mangrove vegetation located about 50m behind the Wellaode plot shows low damage, as a result of being shielded by the mangrove system in the seaward side. The average impact score of the selected mangrove plot at Kahanda-modara was only 1.6, due to the protective function of the elevated beach (dune) at the beach front in that particular area.

In the study plot 8 (near Kunukalliya lagoon), the woody vegetation located in the landward side of the tall and mature sand dune had negligible damage (score

1.1), but a significant impact was observed on the ground cover due to water runoff (score 3). This shows even the tsunami water has flown over the tall sand dune, its destructive force has been effectively reduced. Similarly, analysis of the impact on mangrove vegetation immediately behind the Lunama sand dune in study plot 9 (Lunama mangrove), showed little impact (average impact score of 1.8), emphasising the value of sand dunes as an effective barrier against the tidal surge.

In study plot 10 (Lunama scrubland), the frontline strip of beach scrub vegetation was severely damaged, showing an extremely high impact score of 3.7. The beach was narrow and the beach crest was relatively lower compared to the adjoining stretches and their was no significant dune formation.

At the plot 11 (Ussangoda), scrubland vegetation behind beach near fishery harbour, showed a severe damage with an average impact score of 3.6. This is an area where the beach scrub vegetation was cleared and the beach crest was lowered by pre-tsunami human interventions.

The mangrove system dominated by *Sonneratia caseolaris* in the study plot 12, located closer to the Walawe river and beach in Modaragama area showed a severe impact (average score of 3.6). Removal of large *Terminalia arjuna* trees from the riverine vegetation and thinning of the mangrove strip due to human encroachment have enabled tsunami waves to cause heavy damage in this area.

The structural damage in the plot 13 (Godawaya), where *Casuarina equisetifolia* have been planted on tall and mature sand dunes at beach front, was very low, and can be attributed to the protective function of high dune formation in the area. The *Casuarina* plantation may have improved the tsunami buffering action of the sand dune.

3.3. The protective function of coastal ecosystems against the tsunami

It is interesting to note that study plots shielded by tall mature sand dunes (i.e., old and broad dunes covered with scrubland vegetation), sand rich high statue broad beaches, thick *Pandanus* stands, and *Casuarina* plantations on the beach front have scored low or no impact values, hence they have functioned as effective barriers protecting inland landscapes (Table 2). It was observed that, such intact sand dunes have protected a large part of the Lunama-Kalametiya Sanctuary, while sand dunes stabilized with *Casuarina* plantations have also played a similar role, in the Godawaya area. Sand dune vegetation and *Casuarina* plantations may contribute to a reduced impact by ocean surges. However, it should also be investigated to which extent negative ecological influences occur from such artificially planted barriers [1].

Similarly, intact stands of broad mangroves in estuary/lagoon mouths have also played the role of frontline defence against tsunami water funnelling through those wetlands (Table 2) This is clearly evident in areas such as Medilla, Kalametiya lagoon and Kahandamodara estuary, where the frontline stands of mangrove trees have been destroyed by the tsunami wave, but back stands remain relatively intact.

The facts are illustrated in figure 2, with lower impact in plots having sand dunes, mangroves, and *Casuarina* plantations in beach front, while impact scores are high in plots with low stature beach as the seaward environment. Figure 3 shows how the level of tsunami water incursion has increased when the seaward habitat changes from tall sand dune to low statue beach.

In addition to sand dunes and mangroves, coastal wetlands such as mangrove swamps with creeks, salt marshes, broad estuaries and lagoons, were observed to retain the sea-water and sediments brought in by the tsunami, thereby protecting managed landscapes such as paddy fields and human settlements. Examples of such sites within the study area include the Kiralakelle mangrove swamp, Kahandamodara mangrove swamp and creeks, Medilla mangrove swamp, Welipatanwila salt marsh, Kalametiya and Rekawa lagoons, and the Walawe estuary.

In addition to above observations on the protective role of coastal ecosystems, heavy destructions were caused by the tsunami waves in places where the natural beachfront features have been modified by, cutting of sand dunes, clearing of beachfront vegetation, creating narrow artificial canals connected to the sea, and building infrastructure on the beachfront. It was observed that tourist hotels in Medilla and the Modaragama Village at the coastal floodplain of Walawe river as well as inadequately planned fisheries harbours in Ussangoda, Welipatanwila, Pattiyawaraya and Oruwella been subjected to heavy damage. In areas where sand dunes have been exploited, the damage to inland areas were severe, as evident in the Kalametiya fisheries village and the Welipatanwila area.

Table 2. Level of tsunami impacts in selected sites within the study area in relation to the seaward environment.

Study Plot		Tsunami Impact					Seaward environment	
Plot No.	Site	Mean ground impact score	Mean tree damage impact score	Average impact score	Incursion of tsunami water (m)	Level of impact	Seaward habitat features	Degree of modification (pre-tsunami)
1	Medilla modara	3.9	3.4	3.6	700	Severe impact	Artificial lagoon outlet and low stature sandy beach [Md]	High
2	Medilla mangrove	1.5	1.3	1.4	700	Low impact	Intact Mangove stand [Md]	Low
3	Rekawa mangrove	0.0	1.1	0.6	60	No impact	>5m tall 100m broad sandune and coconut [Rk]	Low
4	Rekawa coconut land	2.4	1.0	1.7	60	Low impact	>2m dune and sandy beach [Rk]	Moderate
5	Oruwella	3.9	4.0	3.9	60	Severe impact	Bay and low stature narrow sandy beach [Or]	High
6	Wellaodae	3.8	3.0	3.4	500	Severe impact	Low stature sandy beach and coconut [Wd]	High
7	Kahandamodara	1.8	1.4	1.6	500	Low impact	Intact Mangove stand [Kh]	Low
8	Kunukalliya	3.0	1.1	2.0	500	Low impact	>5m tall sandune [Kn]	Low
9	Lunama mangrove	2.6	1.1	1.8	75	Low impact	>5m tall broad sandune [Ln]	Low
10	Lunama scrubland	3.9	3.6	3.7	250	Severe impact	Immature dune and sandy beach [Ln]	Low
11	Ussangoda	3.8	3.4	3.6	600	Severe impact	Low stature sandy beach with cleared scrub [Us]	High
12	Modaragama	3.5	3.7	3.6	1000	Severe impact	Immature dune, sandy beach and the river [Wp]	High
13	Godawaya	2.2	1.0	1.6	80	Low impact	Cassuarina on 2-3m sand dune [Gd]	Moderate

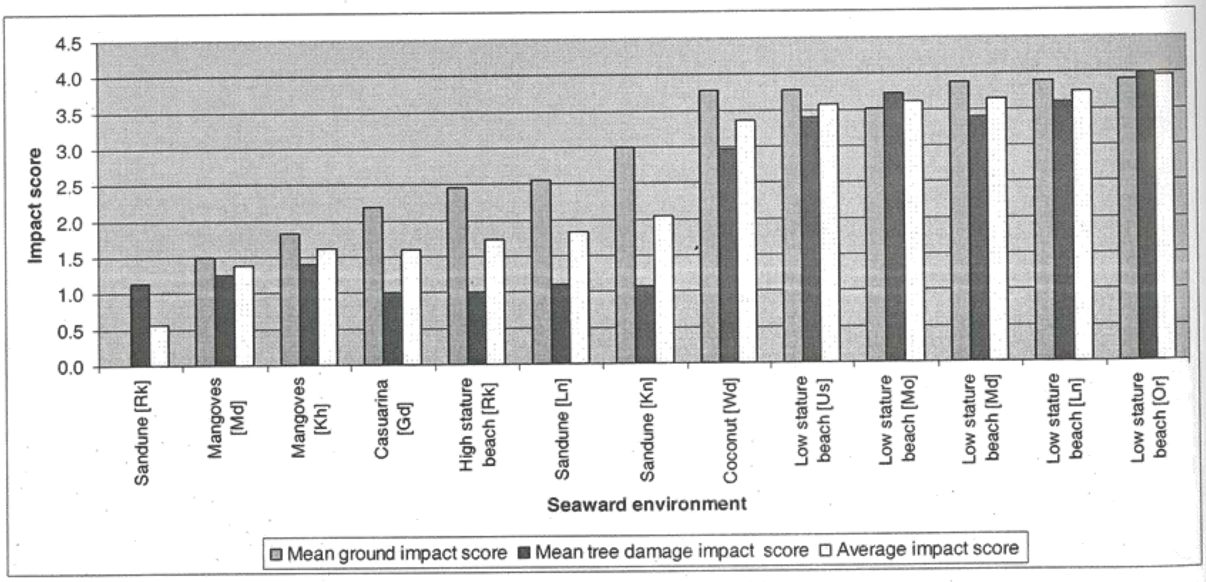

Figure 2. Level of tsunami impact in relation to the seaward habitat

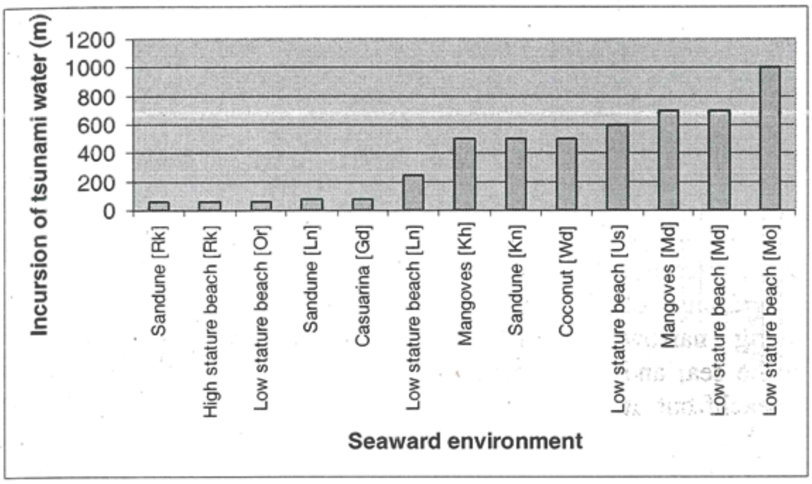

Figure 3. Level of tsunami water incursion in relation to the seaward habitat

Analysis of site-specific quantitative data revealed a positive relationship between tsunami damage in inland areas and man mediated modifications in the associated seaward / beach front environment (Table 2). Figure 4 clearly illustrates study plots with low level of pre tsunami habitat modifications in seaward environment having low tsunami impact scores, and vise versa.

The conversion of mangrove land into shrimp farms, tourist resorts, agricultural or urban land over the past decades, as well as destruction of coral reefs off the coast, have likely contributed significantly to the catastrophic loss of human lives and settlements during the recent tsunami event [1]. Severe damages to inland areas were also visible in places where, people practiced near shore coral mining and bottom-set netting, as the case in Oruwella [9]. Therefore, coastal ecosystems such as coral reefs, rocky beaches, and sand-stone reefs may also have contributed to reduce the force of the tsunami.

However, it should be noted that the level of damage could not always be attributed to the site specific seaward habitat modifications, indicating the need to consider other aspects such as coastal bathymetry, direction of currents and their force, to reach more accurate conclusions.

Few other recent studies have also came out with similar results to show that natural coastal ecosystems are playing a vital role in protecting coastline from tidal surges [1,2]. Measurement of wave forces and modelling of fluid dynamics suggest that tree vegetation may shield coastlines from tsunami damage by reducing wave amplitude and energy. Analytical models show that 30 trees per 100m in a 100m wide belt may reduce the maximum tsunami flow pressure by more than 90% [2, 10].

The story of mangroves and tsunami is but one example of a broader story. Natural ecosystems throughout the world provide tremendous ecosystem services, including protection against extreme weather events and natural catastrophes [11]. When we fail to raise awareness about these functions, and we destroy or degrade the world's natural ecosystems too much, we do so at our own peril [1].

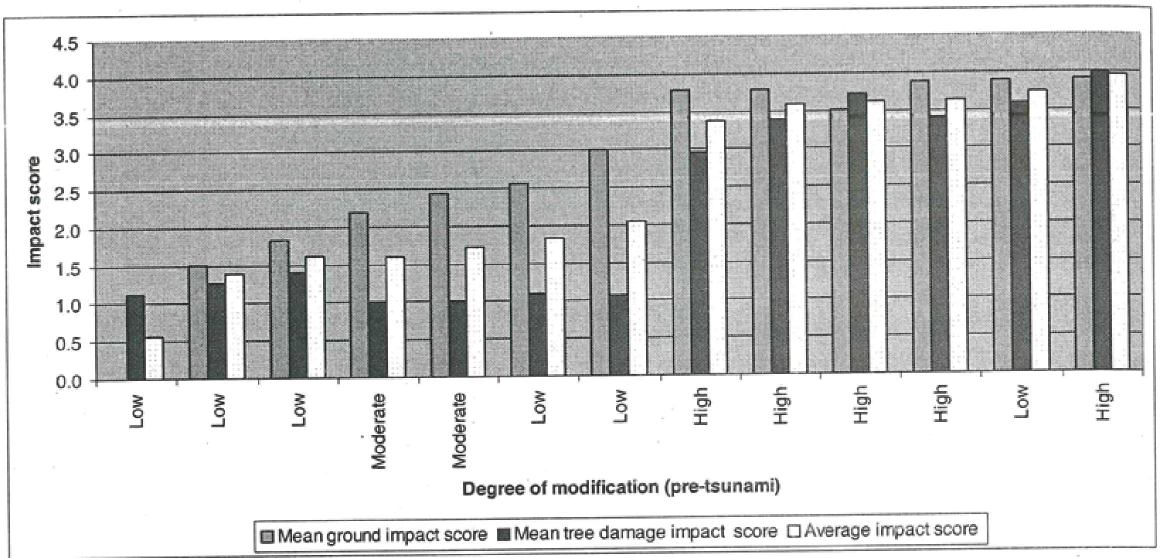

Figure 4. Level of tsunami impact in relation to the degree of modification in seaward habitat

5. Conclusion and Recommendations

The survey has clearly shown that the intact coastal ecosystems, have played a significant role in reducing the impacts of tsunami to inland landscapes that harbour homesteads, agricultural land and tourism infrastructure. From the results we obtained it can be concluded that sites shielded by tall mature sand dunes, and *Casuarina* plantations on the beach front and broad intact mangrove stands bordering coastal wetlands functioned as effective barriers against the tsunami.

Evaluation of tsunami impacts in different study plots within the study area provides a strong understanding of the benefits of maintaining natural coastal ecosystems for the protection of coastal zone.

Therefore, as suggested by Dahdouh-Guebas et al. (2005), while it may be a good investment to establish early warning systems for the next tsunami, it could be far more effective to restore and protect coastal ecosystems as a natural defence in parallel.

Restoration of degraded mangrove vegetation along the coastline and replanting of tsunami affected mangroves, while ensuring their protection and sustainability, should be considered the priority need in protecting Sri Lankan coastline from future catastrophes. Dahdouh-Guebas et al. (2005) concluded that three factors can undermine the ability of mangroves to protect coastal landscapes: first, complete clearance second, insufficient re-growth following a previous clearing; and third, infusion of adult mangroves with excess of non-mangrove vegetation components. Therefore mangrove restoration should be well planned and managed using the appropriate species on appropriate sites.

Mangroves, however, are suitable for planting only on coastal mudflats and lagoons. Elsewhere, the conservation of dune ecosystems or green belts of other tree species could fulfil the same protective role [2]. While replanting of green belts composed of species such as *Pandanus* on the beach front would support the beach protection, it is also important to protect the sub-tidal habitats such as coral reefs from destructive fishing practices and coral mining.

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