Seaweed floristic studies along tsunami affected Indian coasts: A litmus test scenario after 26th December 2004

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On 26th December 2004, the world witnessed the devastating power of tsunami, affecting many countries, bordering the Indian Ocean region. This has caused significant changes in the shallow and intertidal regions of the Indian coast, especially the Andaman and Nicobar Islands, Tamil Nadu, Kerala and Pondicherry. The baseline data on biomass availability and distribution of benthic intertidal seaweed species were collected immediately after this catastrophic event by spot surveying 11 selected localities of the above-mentioned regions. In all, 45 species belonging to 31 genera were recorded during the present survey, the maximum number of seaweed species were recorded at Thirumullavarum, Kerala with the minimum at Car Nicobar, Andaman and Nicobar Islands. A very different trend was observed in the case of biomass availability at some locations which was due to the influence of habitat suitability over the tsunami damage. The details of this study have been provided in the present communication.

1. Introduction

The sheer power of nature unleashed the M 9.0 earthquake of 26th December 2004 at 06:28:53 IST that had originated in the Indian Ocean just north of Simeulue Island, off the western coast of northwest Sumatra. This earthquake led to the devastating tsunami and created the most widespread catastrophe in modern history, particularly seen in Sri Lanka, India, Maldives, Indonesia and Thailand with damaging effects also in Malaysia, Bangladesh, Somalia and Seychelles. The huge tsunami waves caused mass movement of water with immense force, resulting in extensive damage to the nearshore property and major changes in the intertidal areas of the tsunami affected Indian coast (Jain *et al* 2005). Any assessment of the environmental impact of this cataclysmic tsunami will need both time and significant data.

India ranks first among all countries bordering the Indian Ocean ahead of Australia and South Africa (c.f. Sahoo *et al* 2001) in the number of recorded specific and intraspecific seaweed taxa. However, information on the damage and changes to seaweed biota due to the recent tsumani along the Indian coast is not enough (Mantri 2005). Intertidal areas being more favourable for seaweed growth in the Indian waters, floristic studies for benthic, intertidal seaweeds were undertaken by the Central Salt and Marine Chemicals Research Institute, Bhavnagar during the period 15th January to 17th February 2005 along the tsunami affected coasts to assess what is left after 26th December 2004. The present communication is among the early reports about the impact of the recent tsunami on seaweed biota.

2. Materials and methods

Field observations were made during the lowest tide of the *chart datum*. Spot surveys were carried out along 11 localities (5 from Andaman and Nicobar Islands, 3 from Tamil Nadu, 2 from Kerala and 1 from Pondicherry) of tsunami affected Indian coast. All the seaweeds encountered during the

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Table 1. *Checklist of seaweed species present along the tsunami affected Indian coast.*

Locality	Date and time of sampling	Seaweed encountered Family	Species	Availability status
South Point, Port Blair, South Andaman Island 11° 39′ N & 92° 45′ E	15th January 2005 06:15 h	Ulvaceae	*Ulva* sp. (Germling stage)	++
			Enteromorpha flexuosa (Wulfen) J. Agardh	+++
		Cladophoraceae	*Chaetomorpha_ spiralis* Okamura	+
			Cladophora sp.	++
		Dictyotaceae	*Lobophora variegata* (Lomouroux) Womersley ex Oliveira	+
			Padina tetrastromatica Hauck	+++
		Sargassaceae	*Sargassum cristaefolium* C. Agardh*	+++
			Turbinaria conoides (J. Agardh) Kützing*	++
			T. ornata (Turner) J. Agardh*	+++
		Gracilariaceae	*Gracilaria canaliculata* Sonder	++
Malakka, Car Nicobar 09° 10′ N & 92° 49′ E	21st January 2005 13:30 h	Ulvaceae	*Enteromorpha compressa* (Linnaeus) Nees	+++
Diglipur, North Andaman Island 11° 39′ N & 92° 45′ E	29th January 2005 17:00 h	Dictyotaceae	*Padina* sp.	++
			Dictyota sp. (Germling stage)	++
		Sargassaceae	*Sargassum ilicifolium* (Turner) C. Agardh	+++
Mayabandar, Middle Andaman Island 12° 53′ N & 92° 54′ E	30th January 2005 09:00 h	Sargassaceae	*Sargassum* sp.*	++
			T. ornata (Turner) J. Agardh*	+++
		Gelidiaceae	*Gelidium pusillum* (Stackhouse) Le Jolis	++
		Ceramiaceae	*Ceramium* sp.	+
		Rhodomelaceae	*Bostrychia tenella* (Lamouroux) J. Agardh	+++
Rangat, Middle Andaman Island 12° 32′ N & 92° 58′ E	30th January 2005 09:00 h	Ulvaceae	*Enteromorpha* sp.	++
		Dictyotaceae	*Dictyta* sp. Lamouroux	+
Colachal, Tamil Nadu 08° 10′ N & 77° 49′ E	8th January 2005 16:00 h	Ulvaceae	*Ulva fasciata Delile*	++
		Cladophoraceae	*Chaetomorpha antennina* (Bory de Saint-Vincent) Kützing	+++
		Sargassaceae	*Sargassum* sp.	+++
			Sargassum sp.*	+

Table 1. *(Continued).*

Locality	Date and time of sampling	Seaweed encountered Family	Species	Availability status
Kanyakumari, Tamil Nadu 08° 40′ N & 77° 36′ E	9th February 2005 6:30 h	Ulvaceae	*Enteromorpha compressa* (Linnaeus) Nees	++
			Ulva fasciata Delile	+++
			Ulva fasciata Delile*	+
		Cladophoraceae	*Chaetomorpha crassa* (C. Agardh) Kützing	+
		Caulerpaceae	*Caulerpa racemosa* (Forsskål) J. Agardh	++
			Caulerpa racemosa (Forsskål) J. Agardh*	+
		Dictyotaceae	*Dictyopteris delicatula* Lamouroux	+++
			Lobophora variegata (Lomouroux) Womersley ex Oliveira	+++
			Lobophora variegata (Lomouroux) Womersley ex Oliveira*	++
			Padina tetrastromatica Hauck	++
			Padina tetrastromatica Hauck*	+
			Stoechospermum marginatum (C. Agardh) Kützing	+++
			Stoechospermum marginatum (C. Agardh) Kützing*	++
		Chnoosporaceae	*Chnoospora minima* (Hering) Papenfuss	+++
		Sargassaceae	*Sargassum* sp.	+++
		Gelidiaceae	*Pterocladia* sp.	+
		Gracilariaceae	*Gracilaria foliifera* (Forsskål) Børgesen	++
			G. corticata (J. Agardh) J. Agardh	+++
			G. debilis (Forsskål) Børgesen	+++
			G. debilis (Forsskål) Børgesen*	+
		Halymeniaceae	*Cryptonemia undulata* Sonder	+++
		Rhizophyllidaceae	*Portieria hornemannii* (Lyngbye) P. Silva	++
		Hypneaceae	*Hypnea valentiae* (Turner) Montage	+++
			Hypnea valentiae (Turner) Montage*	+++
		Rhodymeniaceae	*Botryocladia leptopoda* (J. Agardh) Kylin	+
		Dasyaceae	*Dictyurus purpurascens* Bory de Saint-Vincent*	+

Table 1. *(Continued).*

Locality	Date and time of sampling	Seaweed encountered Family	Species	Availability status
Varakala, Kerala 08° 28′ N & 77° 55′ E	10th February 2005 17:00 h	Ulvaceae	*Enteromorpha* sp.	+ + +
			Ulva sp.	++
		Sargassaceae	*Sargassum*_*wightii* Greville*	+
Thirumullavarum, Kollam, Kerala 08° 54′ N & 76° 38′ E	11th February 2005 16:30 h	Ulvaceae	*Enteromorpha thirumullavaramensis* Sulekha and Panikkar$	+ + +
			Ulva lactuca Linneaus	+
			U. fasciata Delile	++
			U. fasciata Delile*	+
			U. rigida C. Agardh	+
		Acrosiphoniaceae	*Acrosiphonia orientalis* (J. Agardh) P. Silva	+ + +
			Acrosiphonia orientalis (J. Agardh) P. Silva*	+
		Cladophoraceae	*Chaetomorpha antennina* (Bory de Saint-Vincent) Kützing	++
		Valoniaceae	*Valoniopsis pachynema* (G. Martens) Børgesen	++
		Caulerpaceae	*Caulerpa peltata* Lamouroux	+
			C. racemosa (Forsskål) J. Agardh	+ + +
			C. sertularioides (S. Gmelin) Howe	++
		Ectocarpaceae	*Feldmannia indica* (Sonder) Womersley and Bailey	+
		Dictyotaceae	*Lobophora variegata* (Lomouroux) Womersley ex Oliveira	++
			Padina gymnospora (Kützing) Sonder	+ + +
			Stoechospermum marginatum (C. Agardh) Kützing	++
			Stoechospermum marginatum (C. Agardh) Kützing*	+
		Sargassaceae	*Sargassum tenerrimum* J. Agardh	+ + +
			*Sargassum*_sp.	++
			Sargassum tenerrimum J. Agardh*	+
		Gelidiellaceae	*Gelidiella acerosa* (Forsskål) J. Feldmann and G. Hamel	+
		Gracilariaceae	*Gracilaria foliifera* (Forsskål) Børgesen	++
			Gracilaria foliifera (Forsskål) Børgesen*	+
		Halymeniaceae	*Cryptonemia undulata* Sonder	+ + +

Table 1. *(Continued).*

Locality	Date and time of sampling	Seaweed encountered Family	Species	Availability status
		Rhizophyllidaceae	*Portieria hornemannii* (Lyngbye) P. Silva	+ + +
		Corallinaceae	*Jania adhaerens* Lamouroux	++
			Cheilosporum spectabile Harvey ex Grunow	+
		Hypneaceae	*Hypnea valentiae* (Turner) Montage	+ + +
			Hypnea valentiae (Turner) Montage*	+
		Rhodymeniaceae	*Gelidiopsis variabilis* (J. Agardh) Schmitz	++
		Ceramiaceae	*Ceramium cruciatum* Collins and Hervey	+
		Rhodomelaceae	*Laurencia* sp.	++
Karaikal, Pondicherry 10° 55′ N & 79° 52′ E	15th February 2005	Ulvaceae	*Enteromorpha* sp.	+ + +
		Cladophoraceae	*Chaetomorpha aerea* (Dillwyn) Kützing	++
Kodiakkarai (Point Calimere) Tamil Nadu 10° 17′ N & 79° 52′ E	16th February 2005	Ulvaceae	*Enteromorpha* sp.	+
		Cladophoraceae	*Rhizoclonium* sp.	+

Note: + meager, ++ average, + + + dominant; *drift collection.
$*Enteromorpha thirumullavaramensis* species novo. Sulekha and Panikkar.
Source: Studies on the seasonal distribution and taxonomy of the marine green algae of Kerala, India, Ph.D. Thesis, University of Kerala, pp. 292.

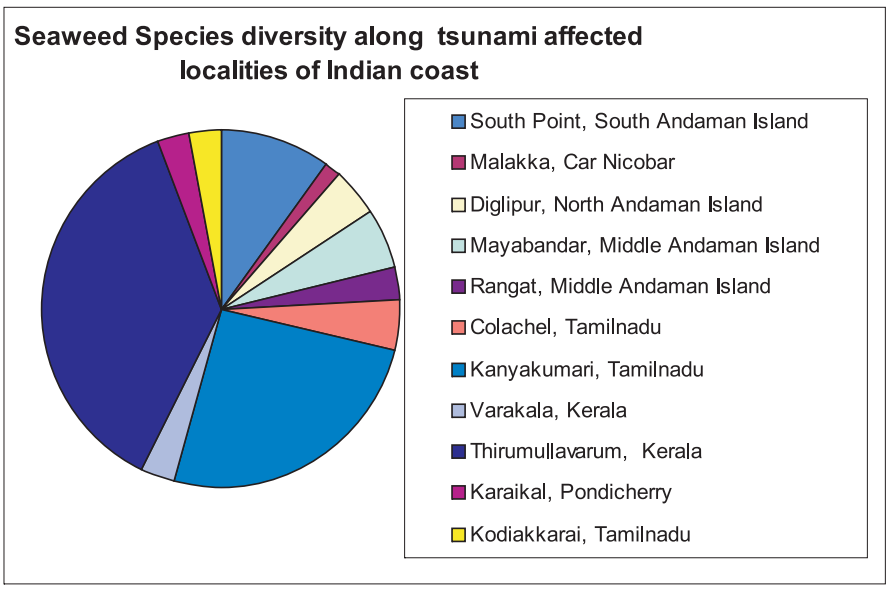

Figure 1. Seaweed diversity of affected places.

Table 2. *Biomass availability of seaweed species in some selected localities of tsunami affected regions of the Indian coast.*

Locality	Species	Average biomass (SD) g (dry) m^{-2}
South Point, Port Blair, South Andaman Island	*Ulva* sp.	0.97 (±1.40)
	Enteromorpha flexuosa (Wulfen) J. Agardh	2.88 (±2.22)
	Chaetomorpha spiralis Okamura	0.962 (±1.44)
	Cladophora sp.	2.22 (±1.68)
	Lobophora variegata (Lomouroux) Womersley ex Oliveira	4.75 (±4.03)
	Padina tetrastromatica Hauck	6.79 (±4.70)
	Gracilaria canaliculata Sonder	4.34 (±6.06)
Malakka, Car Nicobar	*Enteromorpha compressa* (Linnaeus) Nees	6.98 (±4.76)
Diglipur, North Andaman Island	*Padina* sp.	13.44 (±8.98)
	Dictyota sp.	15.15 (±10.73)
	Sargassum ilicifolium (Turner) C. Agardh	27.92 (±13.14)
Colachal, Tamil Nadu	*Ulva fasciata* Delile	14.24 (±6.27)
	Chaetomorpha antennina (Bory de Saint-Vincent) Kützing	6.46 (±1.97)
	Sargassum sp.	10.67 (±10.63)
Kanyakumari, Tamil Nadu	*Enteromorpha compressa* (Linnaeus) Nees	22.05 (±7.98)
	Ulva fasciata Delile	33.33 (±16.31)
	Chaetomorpha crassa (C. Agardh) Kützing	15.23 (±9.82)
	Caulerpa racemosa (Forsskål) J. Agardh	147.65 (±69.26)
	Dictyopteris delicatula Lamouroux	9.63 (±9.44)
	Lobophora variegata (Lomouroux) Womersley ex Oliveira	41.01 (±9.89)
	Padina tetrastromatica Hauck	107.54 (±95.03)
	Stoechospermum marginatum (C. Agardh) Kützing	10.08 (±6.35)
	Chnoospora minima (Hering) Papenfuss	31.69 (±44.87)
	Sargassum sp.	316.88 (±88.75)
	Pterocladia sp.	12.39 (±12.43)
	Gracilaria foliifera (Forsskål) Børgesen	129 (±132.77)
	G. corticata (J. Agardh) J. Agardh	88.67 (±108.30)
	G. debilis (Forsskål) Børgesen	3.16 (±6.82)
	Cryptonemia undulata Sonder	17.8 (±39.80)
	Portieria hornemannii (Lyngbye) P. Silva	3.02 (±2.81)
	Hypnea valentiae (Turner) Montage	149.254 (±37.37)
	Botryocladia leptopoda (J. Agardh) Kylin	9.74 (±7.87)
Varakala, Kerala	*Enteromorpha* sp.	6.61 (±6.13)
	Ulva sp.	12.88 (±7.40)
Thirumullavarum, Kollam, Kerala	*Enteromorpha thirumullavaramensis* Sulekha and Panikkar	6.88 (±4.09)
	Ulva lactuca Linneaus	14.56 (±8.39)
	U. fasciata Delile	39.36 (±27.46)
	U. rigida C. Agardh	14.14 (±2.68)
	Acrosiphonia orientalis (J. Agardh) P. Silva	17.12 (±9.90)
	Chaetomorpha antennina (Bory de Saint-Vincent) Kützing	13.08 (±9.21)
	Valoniopsis pachynema (G. Martens) Børgesen	24.11 (±23.60)
	Caulerpa peltata Lamouroux	41.42 (±29.35)
	C. racemosa (Forsskål) J. Agardh	7.18 (±5.52)
	C. sertularioides (S. Gmelin) Howe	15.64 (±24.03)

Table 2. *(Continued).*

Locality	Species	Average biomass (SD) g (dry) m^{-2}
	Feldmannia indica (Sonder) Womersley and Bailey	1.01 (±1.14)
	Lobophora variegata (Lomouroux) Womersley ex Oliveira	7.36 (±7.04)
	Padina gymnospora (Kützing) Sonder	22.47 (±19.66)
	Stoechospermum marginatum (C. Agardh) Kützing	10.69 (±3.96)
	Sargassum tenerrimum J. Agardh	27.20 (±35.01)
	Sargassum sp.	130.54 (±42.94)
	Gelidiella acerosa (Forsskål) J. Feldmann and G. Hamel	13.69 (±13.13)
	Gracilaria foliifera (Forsskål) Børgesen	18.16 (±4.32)
	Cryptonemia undulata Sonder	1.24 (±1.89)
	Portieria hornemannii (Lyngbye) P. Silva	0.57 (±0.80)
	Jania adhaerens Lamouroux	3.83 (±3.84)
	Cheilosporum spectabile Harvey ex Grunow	0.916 (±2.04)
	Hypnea valentiae (Turner) Montage	6.87 (±2.87)
	Gelidiopsis variabilis (J. Agardh) Schmitz	0.89 (±1.24)
	Ceramium cruciatum Collins and Hervey	0.26 (±0.39)
	Laurencia sp.	0.25 (±0.55)
Kodiakkarai (Point Calimere) Tamil Nadu	*Enteromorpha* sp.	0.312 (±0.69)
	Rhizoclonium sp.	0.09 (±0.20)

Table 3. *Species similarity index for selected tsunami affected location of the Indian coast.*

Locations	Similarity index
South Point, Port Blair vs. Kanyakumari	0.077
South Point, Port Blair vs. Thirumullavarum	0.030
Kanyakumari vs. Thirumullavarum	0.157

study were identified, recorded and classified as meager (+), average (++) and dominant (+++) based on their occurrence in the natural habitat. Few of the sample materials were preserved in 4% formaldehyde in seawater for further critical observation. The biomass availability was recorded for eight coastal locations viz., South Point (11° 39′ N & 92° 45′ E), Port Blair, south Andaman Island; Malakka (09° 10′ N & 92° 49′ E), Car Nicobar; Diglipur (11° 39′ N & 92° 45′ E), north Andaman Island; Colachal (08° 10′ N & 77° 49′ E), Tamil Nadu; Kanyakumari (08° 40′ N & 77° 36′ E), Tamil Nadu; Varakala (08° 28′ N & 76° 55′ E), Kerala; Thirumullavarum (08° 54′ N & 76° 38′ E) Kollam, Kerala; Kodiakkarai (10° 17′ N & 79° 52′ E) Tamil Nadu by placing 5 random quadrates of 0.5 m^2 size. Seaweeds collected from these quadrates were brought to a laboratory washed thoroughly to make them free from sediments and epiphytic animals, air dried followed by hot oven drying at 60°C for 48 h and the biomass was then estimated as 'g dry weight m^2'. The voucher specimens were given accession numbers and deposited at '*Marine Algae Herbarium*', Central Salt and Marine Chemicals Research Institute, Bhavnagar, India as reference material. The species similarity index (Margalef 1968) for selected localities was calculated for comparison of seaweed diversity.

3. Observations and discussion

Though many places along eastern coastal India have been affected during the recent tsunami, Andaman and Nicobar and coastal Tamil Nadu and Kerala, are of immediate concern since they are rich in seaweed wealth (Krishnamurthy *et al* 1980; Krishnamurthy 1991; Nair *et al* 1986; Rao 2000). On-the-spot verification at all the 11 localities revealed the presence of 15 species of seaweeds belonging to 14 genera of Rhodophyta,

15 species to 9 genera of Phaeophyta and 15 species to 8 genera of Chlorophyta (table 1). Maximum species diversity was recorded at Thirumullavarum coast, Kerala with the least from Car Nicobar, Andaman and Nicobar Islands (figure 1). The high seaweed floristic diversity (24 seaweed species, 32.43%) found at Thirumullavarum coast could be ascribed to the least tsunami damage in this area and less diverse flora (only 1 seaweed species, 1.35%) observed at Car Nicobar, could be the result of supercilious damage here. However, the influence of habitat suitability over tsunami damage was more pronounced at some localities, which was reflected in biomass availability viz., rich seaweed growth at Kanyakumari [*Sargassum* sp. recorded 316.88 ± 88.75 g (dry) m^{-2}] and poor seaweed growth at Kodiakkarai (Point Calimere) [0.09 ± 0.20 g (dry) m^{-2}] (table 2). The comparison of seaweed flora at South Point, Port Blair, south Andaman Island, Kanyakumari and Thirumullavarum showed comparatively higher value for Kanyakumari vs. Thirumullavarum (table 3). The dissimilarity of this biological variable is obvious and could be related to the special variation and environmental, physico–chemical and geographical features at these locations (Anonymous 1978).

In conclusion, to understand the long-term ecological consequences due to the recent Asian tsunami, we need to have more detailed studies. Immediate assessment of the loss of seaweed biodiversity at the localities under study was not possible since the corresponding data prior to tsunami for these localities were not available. Though some information for a few affected places is available, (Srinivasan 1969, 1973; Krishnamurthy and Joshi 1970; Nair *et al* 1982; Chennubhotla *et al* 1991; Jagtap 1992; Chennubhotla 1992; Kaliaperumal and Kalimuthu 1993) it is too old and fragmentary for any genuine comparison. The present study is in no way extensive and complete; but still it will be useful and could be taken as new baseline record for future biomonitoring studies.

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