A Protocol for Ecological Monitoring of Sandy Beaches and Intertidal Fauna on the Indian Coast

November 2008

Terenia Berlie, Naveen Namboothri, Anjana Mohan and Kartik Shanker
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Citation

United Nations team for Tsunami Recovery Support (UNTRS)
Apex Towers, 4th floor, 54, 2nd Main Road,
R.A. Puram, Chennai-600028, India.
Tel: 91-44-42303551
www.un.org.in/untrs
(valid for the project period only)

The United Nations, India
55 Lodi Estate, New Delhi-110003, India.
Tel: 91-11-46532262, 46532333
www.un.org.in
www.un.org.in/untrs

Ashoka Trust for Research in Ecology and the Environment
No. 659, 5th A Main, Hebbal, Bangalore 560024, India.
Tel: 91-80-23533942, 23530069, 23638771
www.cmp-atree.org
email: naveen.namboo@gmail.com

Photo credits: A. Mohan, T. Berlie, N. Namboothri and Chandrashekar
Front cover photo: Sandy beach at Valinokkam, Tamil Nadu, India (Photo credit: A. Mohan, 2007)

Design and Layout: Arjun Shankar and Seema Shenoy, with Ecotone.
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Sandy beaches make up two-thirds of the world’s coastlines (McLachlan & Brown 2006). Not only are they valuable from an aesthetic and recreational perspective, they also are the first line of defense against the ravages of the sea, and bear the brunt of the impacts of the lashing waves. To the casual observer, an intertidal sandy beach may seem to be devoid of any life. But on the contrary, the ocean beach is teeming with a spectrum of life, both visible to the naked eye and microscopic.

The sandy beach is a high energy and dynamic ecosystem, where sand and water are always in constant motion. The major physical factors determining life on the sandy beach are waves, tides and sand. These factors interact in different ways, controlling the sand budget (a key coastal process), resulting in beaches of varying profiles, which in turn determine the fauna that live in these habitats.

The sandy shore fauna are a highly adapted, diverse and ecologically significant group. But these forms, due to their inconspicuous nature, are a much overlooked group. The intertidal sandy shore fauna on one hand are highly sensitive to disturbance (both natural and human), but on the other hand are also found to be highly resilient and adaptive (McLachlan & Brown 2006). Benthic fauna in general are reported to be excellent indicators of stress on the ecosystem and pollution.

Sandwiched between rising sea levels and impoverished supply of sand from the seaward side, and increasing human activity and development on the landward side, sandy shores are under severe pressure along the Indian coast. With rapidly increasing concerns over the rise in sea levels, bloating human population, coastal development, and demand for coastal recreation, it is not surprising that Coastal Zone Management (CZM) is particularly focused on sandy shores. Coastal erosion is a major concern in many parts of the west and east coast of India. Using hard defensive structures like seawalls only provides a temporary solution to erosion and could also aggravate the process of erosion in the long run if they affect
the sand budget of the coast. Sediment dynamics of coastal areas is a
dynamic and vital process, which needs to be properly understood before
undertaking coastal construction or developmental activities. Profiles of
beaches are much affected by both natural and anthropogenic impacts, as
are the fauna of intertidal sandy shores.

A first step to understanding changes to the shoreline and its faunal
components is identifying a set of indicative parameters and monitoring
them on a long-term basis. While there is considerable literature on
monitoring protocols and sampling methods, most of them lie scattered
in reports and journals that are not readily accessible to managers. The
objective of this manual is to serve as a monitoring protocol for managers
intending to monitor sandy beaches. Though there is debate over sampling
methods and appropriate sample sizes, the current recommendations are
based on field tests, and logistical and technical practicality of sampling
over a large area. This protocol is designed for studies that cover a large
area (more than 200 km/more than 10 sites). For a more localised study
aimed at understanding spatio-temporal variations or addressing more
specific questions on ecosystem function and dynamics, more intensive
sampling may be required. In this manual, we focus on three major
components that need to be monitored on a regular basis in order to
characterise ecosystem health and understand nearshore processes:

1. Beach Profiling
2. Intertidal soft-bottom benthic fauna (macro and megafauna)
3. Biotic and abiotic parameters
2. Beach Profiling

2.1 Types of beaches and their characteristics

The interaction of waves, tides and the sand results in beaches of different profiles and shapes, which in turn define the fauna that live there. Beaches are generally classified into three major categories based on their shape and vertical profile.

Reflective beaches:

Reflective beaches reflect most of the incoming wave and are steeper than intermediate and dissipative beaches. The slope is caused by accretion from swell waves. The surf zone is less than 10m wide (Bird 2008) and they have coarse sediments that filter most of the water (Knox 2001).

Waves play a major role in determining the profile and fauna of these beaches. The following habitat conditions and fauna are generally encountered on reflective beaches (Figure 1):

1. Steep gradients
2. High wave energy and constantly disturbed environment
3. Larger sand particle size
4. Higher permeability/ poor moisture retention and loose sand
5. Narrow intertidal range (microtidal)
6. Higher oxygen levels in the interstitial environments
7. Impoverished species richness
8. Highly motile and rapidly burrowing forms

Dissipative beaches:

Dissipative beaches are broader and flatter, with a surf zone more than 100m wide (Bird 2008). Tides play a major part in determining the faunal composition, and the beaches are associated with low wave energy (Figures 1 and 4). They consist mainly of fine sand to mud, with high
water retention, poor filtration, low oxygen content and higher organic carbon retention (Knox 2001; McLachlan & Brown 2006).

Dissipative beaches are generally governed by tides. The following habitat conditions and fauna are generally encountered on dissipative beaches (Figure 2):

1. Gradual gradient of the beach face
2. Low wave energy, comparatively less disturbance of sand and water
3. Fine, well sorted and compact sand grains
4. Poor permeability/high moisture retention due to compact nature of sand
5. A wide intertidal range (macrotidal)
6. Poor oxygen levels in the interstitial environment
7. High species richness
8. Dominated by slow moving/ sedentary forms

**Intermediate beaches:**

Intermediate beaches have intermediate characters of reflective and dissipative beaches (McLachlan & Brown 2006), and the degree of sand stored on the beach and in the surf zone varies temporally (Knox 2001). Intermediate beaches have a combination of high to moderate wave energy and medium to fine sediment which results in a transitional beach (Bird 2008) (Figures 5 and 6). Such beach morphotypes may also occur when a reflective beach is being modified to a dissipative beach or vice versa (Bird 2008).

As the name suggests, these are beaches are at various intermediate stages, between that of dissipative and reflective beaches and have characteristics of both reflective beaches and dissipative beaches (Figures 3 and 4).
Types of beaches

Figure 1. Reflective beach - Ovari (Tamil Nadu)

Figure 2. Dissipative beach - Nagapattinam (Tamil Nadu)

Figure 3. Intermediate beach - Karaikkal (Pondicherry)

Figure 4. Intermediate beach - Kovallam (Tamil Nadu)
Beaches are in constant motion, continually changing shape and shifting position in response to winds, waves, tides, relative sea level, and human activities. Significant changes occur seasonally and following storms. During summer, beaches are generally higher and sandier than they are in winter. During winter, the ‘missing’ sand moves from the beach to nearshore areas to form sandbars.

Beach profiling is a method which involves using equipment to determine the level of a beach relative to a vertical point. It is one way to obtain information about seasonal and storm-induced beach shapes. Beach profiling is also quite important in determining the impacts of human disturbance to the structure of beaches and sand budgets.

Every beach has its own sand budget and distinct profile which depends on existing natural factors such as winds, waves, storms, tides and anthropogenic factors such as tourist activity on the beach, fishing related activities, coastal protection structures such as sea-walls and groynes, other constructions such as buildings and resorts, and sand mining activities. Considering that a large percentage of the population in India lives in coastal areas, and that the beaches are a major factor in dampening the impacts of storms and surges, it becomes necessary to understand the changes in the profile of a beach. Monitoring beach profiles over the long term becomes all the more important, considering the increasing threats of global warming and sea level rise. Long-term patterns of beach profile changes can also be valuable for coastal development planning and in the context of coastal area management.

The most extensively used method for beach profiling is the Emery method (Emery 1961) which is a low-cost, low-tech and accurate method.
Emery method for beach profiling

Equipment required

1. GPS with minimal error (lesser than 5 m)
2. 5-10 poles or aluminium angles of ~ 2.5 m length graduated in cm
3. Measuring tape
4. Data sheets (Table 1)
5. Data sheet holder

Recording coordinates and setting up landmarks:

1. A monitoring site needs to be selected at the beach to be monitored. It is necessary to identify or establish permanent identification marks to make it possible to locate the exact site for repeating the measurements. Record this point on the GPS.
2. Fix the first station close to where vegetation or permanent structures begin. Record this point as station 1 on the GPS and fix a pole. This pole serves as the index.
3. Set up another pole (pole 2 = station 2, in front of pole 1) at about 3-5 metres from the index pole. Each successive pole needs to be set up at a point where the beach slope changes substantially.
4. Stand at pole 1 and note the reading on the pole 1 that coincides with the horizon (line where sky meets sea) (Figure a).
5. Standing at pole 1, mark the point on pole 2 that coincides with the point on pole 1 (already marked in step 4) (Figure b).
6. Note the difference in height between the points where the two poles meet the horizon, and the distance between the two poles. This will later be plotted as shown in Figures 7 to 9.
7. Fix a third pole (away from pole 2, towards the horizon) again in line with the first two poles, at the point where depressions/mounds in the beach, if any, begin and end OR at the same distance as in step 3. (Figure c). Repeat steps 4 through 7 as before for poles 2 and 3 standing at pole 2.
8. Repeat the process successively till the low-tide level is reached.
9. The raw data can is then plotted on a graph using a worksheet (Figures 7-9).
Point on pole 1 coincides with the horizon

Beach

Pole 1/ Station 1

Figure a

Pole 1/ Station 1

Line of sight should be in alignment with point A and B on both poles and should also coincide with the horizon

Permanent structure

Permanent identification mark

Distance between pole 3 to 5 meters

Figure b

Pole 1/ Station 1

Pole 2/ Station 2

Line of sight should be in alignment with point A and B on both poles and should also coincide with the horizon

Measure the distance between the poles and note it down

Figure c

Pole 3/ Station 3

High tide

Low tide

8
Figure 5. Choosing a permanent landmark

Figure 6. Measuring the beach profile
Table 1. A typical data sheet to record points for the beach profile

<table>
<thead>
<tr>
<th>Beach Profile</th>
<th>Date: 25.09.08</th>
<th>Location: Alanthalai-ATT1</th>
<th>Latitude: N 08 27.922</th>
<th>Longitude: E 078 06.069</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance between poles</strong></td>
<td><strong>Readings on current and successive pole</strong></td>
<td><strong>Elevation (cm) = B - A</strong></td>
<td><strong>Elevation (m)</strong></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>4.28</td>
<td>A 80</td>
<td>B 79</td>
<td>-1</td>
</tr>
<tr>
<td>II</td>
<td>4.45</td>
<td>A 65</td>
<td>B 75</td>
<td>10</td>
</tr>
<tr>
<td>III</td>
<td>4.45</td>
<td>A 65</td>
<td>B 70</td>
<td>5</td>
</tr>
<tr>
<td>IV</td>
<td>2.70</td>
<td>A 70</td>
<td>B 89</td>
<td>19</td>
</tr>
<tr>
<td>V</td>
<td>0.90</td>
<td>A 75</td>
<td>B 92</td>
<td>17</td>
</tr>
<tr>
<td>VI</td>
<td>2.90</td>
<td>A 80</td>
<td>B 117</td>
<td>37</td>
</tr>
<tr>
<td>VII</td>
<td>4.40</td>
<td>A 55</td>
<td>B 127</td>
<td>72</td>
</tr>
<tr>
<td>VIII</td>
<td>3.40</td>
<td>A 60</td>
<td>B 123</td>
<td>63</td>
</tr>
<tr>
<td>IX</td>
<td>5.25</td>
<td>A 60</td>
<td>B 135</td>
<td>75</td>
</tr>
</tbody>
</table>
Graphs showing the profile of the beach:

Figure 7. Profile of a reflective beach – Alanthalai, Tamil Nadu

Figure 8. Profile of a dissipative beach – Devipattinam, Tamil Nadu

Figure 9. Profile of an intermediate beach – Ovari, Tamil Nadu
3. Nearshore intertidal soft-bottom benthic fauna (macro and mega)

Different beach types have different assemblages of fauna, e.g. dissipative beaches have a much wider intertidal area, less wave induced disturbance than reflective beaches, with considerably smaller grain size. Dissipative beaches show a higher abundance and richness of intertidal species (e.g. crustaceans), while reflective beaches have an impoverished faunal composition. Mud flats with high organic matter and clay content have very few interstitial fauna, but on the other hand support a diverse population of larger fauna that are capable of making burrows or tubes and able to communicate with the water column.

The intertidal sandy shore benthic communities are highly sensitive to minute ecological changes, and need long term and effective monitoring. Benthic species, owing to their sessile and sedentary lifestyles, cannot move away in search of healthier areas and hence tend to accumulate considerable amounts of pollutants from the habitat. In addition, being filter or deposit feeders, many of them bio-magnify pollutants. They are also excellent indicators of human disturbance.

The macrofauna seen on beaches are mainly infaunal species like polychaetes, oligochaetes, archiannelids, nematodes, nemerteans, sipunculans, echiurans, amphipods, isopods, etc. Some prefer sheltered beaches with fine grain size which makes it easier for them to burrow in, and others like isopods and amphipods are found where the sand is coarse.

Megafauna seen on sandy shores are mostly highly mobile due to the changing environmental conditions. The species found on beaches that are between intermediate and reflective have turbulent surf zone and are mainly filter/suspension feeders like bivalves (Donax sp.) and the mole crab (Emerita asiatica). These organisms generally dominate the fauna of exposed beaches. Areas that are more dissipative, sheltered and have fairly gradual changes in tidal ranges harbour deposit feeders like gastropods.
(Bullia vittata, Olivancellaria gibbosa), bivalves (Gafrarium tumidum, Sunetta scripta, etc.) crabs (Dotilla sp.) and other animals that prefer reasonably stable habitats. Here, deposit feeders are seen to dominate the faunal assemblage.

3.1 Methodology

Sampling

A prerequisite to designing a sampling strategy are clear objectives and questions. For example, to study general changes in beach shape and profile, or in faunal compositions of nearshore intertidal communities, sampling can be carried out twice a year (one for the summer and one for the monsoons) over a long term. To examine seasonal changes, four sampling visits a year (every three months) may be required over two-three years to discern patterns. There is marked seasonal variations in the faunal abundance and composition of intertidal sandy shore fauna on the south west coast of India, which gets exposed to the near storm like conditions during the peak monsoon. Little is known about seasonal changes in faunal composition on the east coast of India. To understand the impacts of human disturbance to the coast (seawall, groynes, ports, breakwaters or other such similar coastal construction), one can document changes in beach profiles over a long term (5-10 years).

Transect

Samples are collected along a transect perpendicular to the beach, extending from the high tide to low tide level (Figure 10). Depending on the requirements of the study, the number of transects may be decided. But in order to get a representative sample of a particular beach, at least two transects (about 200 metres apart) should be sampled per beach.
Figure 10. Sample design for a single transect
Collection of samples

Sampling of intertidal sandy shore fauna is done usually using quadrats or cores. A core is better as it does not involve disturbing the sand/sediment within and thereby prevents the escape of motile fauna, while quadrats require excavating the sand/sediment within for the required depth and this may lead to loss of many motile infauna.

Collection of sediment for macrofauna is done to a depth of 25-30 cm using a core of 15 cm diameter (Figure 11). Four cores for macrofauna are collected at each tidal level (high, mid and low tide level), yielding a total of 12 cores per transect (Figure 10).

Collection of sediment for megafauna is done to a depth of 25-30 cm using a core of 25 cm diameter (Figure 12). Five samples for megafauna are also collected randomly in a 2 m² area between the low tide and mid tide level (Figure 10).

Sieving

The sediment samples for macrofauna (Figures 19-24) and megafauna (Figures 25-34) can be sieved on field using a 500 µm sieve (Figure 13) and a 2 cm sieve respectively (Figure 14). Care should be taken not to lose fauna during the process of sieving. One core of 15 cm x 25 cm may take fifteen minutes to half an hour to sieve thoroughly. They can be then transferred into labelled packets and preserved in 5% buffered formalin, stained with Rose Bengal.
Collection of samples

Figure 11. Collection of macrofauna using a 30 cm diameter core

Figure 12. Collection of megafauna using a 25 cm diameter core

Sieving

Figure 13. Sieving of macrofauna on field

Figure 14. Sieving of megafauna on field
Packing

While sampling over a large stretch, a considerable volume of sand gets accumulated in time and traveling becomes a cumbersome issue. It is therefore ideal to pack and send samples back to the laboratory regularly as they accumulate. The sample preserved in packets can be packed in plastic buckets or into wooden crates. Care should be taken not to overload the crates or buckets as they may break during transit. (Figures 15-17).

Figure 15. Packing of sediment samples in wooden crates

Figure 16. Loading of samples in wooden crates to be transported to the laboratory

Figure 17. Transporting of samples in well packed buckets
3.2 Laboratory Analysis

Macro and megafauna:

The stained macrofauna samples should be sorted from the sediment, counted and preserved in 75% alcohol. They can be stored in air tight plastic vials and labelled according to the site, date of collection, GPS coordinates, etc. Specimens to be identified are examined either under a stereo-dissecting microscope or a compound microscope, or both, depending on the characters that need to be observed. Direct counts of specimens are made, or in the case of large abundances of one taxon, subsampling is performed and total counts of the taxon estimated.

Being a neglected and poorly studied group, identification of intertidal soft-bottom fauna is quite challenging. Expert help is recommended if undertaking a species level study. Moreover, the classification of these fauna is based on many microscopic anatomical and structural differences, which can be a laborious and time consuming process. Even before consulting experts, the fauna need to be sorted into larger taxonomic groups. A group level classification can be done based on certain morphological and external characters. Figures 18-33 illustrate the different taxonomic groups generally encountered on the beaches of the east coast.

Once sorted into different groups, the sample should be preserved in 75% ethanol in individual, labeled vials.
Images of common macrofaunal groups encountered on the beaches of Tamil Nadu

Figure 18. Amphipod

Figure 19. Archiannelid
Figure 20. Capitellid

Figure 21. Glycerid
Figure 22. Pisionid

Figure 23. Polydorid
Images of some of the common megafanua encountered on the beaches of Tamil Nadu

Figure 24. *Donax faba*

Figure 25. *Donax cuneatus*
Figure 26. Certhidea cingulata

Figure 27. Umbonium vestiarium
Figure 28. *Lucina edentula*

Figure 29. *Cardita bicolor*
Figure 30. *Nassarius stollatus*

Figure 31. *Unidentified bivalve*
Figure 32. *Emeritaasiatica* - dorsal view

Figure 33. *Emeritaasiatica* - ventral view
**Table 2. Grain size scale adopted in the GRADISTAT program, modified from Udden (1914) and Wentworth (1922)**

<table>
<thead>
<tr>
<th>Types</th>
<th>Generic Name</th>
<th>Particle diameter (mm)</th>
<th>phi (Ø)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Very Coarse</td>
<td>1 to 2</td>
<td>0 to -1</td>
</tr>
<tr>
<td></td>
<td>Coarse</td>
<td>0.5 to 1</td>
<td>1 to 0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.25 to 0.5</td>
<td>2 to 1</td>
</tr>
<tr>
<td></td>
<td>Fine</td>
<td>0.125 to 0.25</td>
<td>3 to 2</td>
</tr>
<tr>
<td></td>
<td>Very Fine</td>
<td>0.0625 to 0.125</td>
<td>4 to 3</td>
</tr>
<tr>
<td>Mud</td>
<td>Silt</td>
<td>0.0039 to 0.0625</td>
<td>8 to 4</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>&lt; 0.0039</td>
<td>&gt; 8</td>
</tr>
</tbody>
</table>

See Section 4.1 on page 29
4. Abiotic and biotic parameters

The fauna present on the beach depends on the type of beach, beach slope, grain size, organic carbon in the sediment and a range of other biotic and abiotic parameters. These parameters determine their distribution, abundance and diversity in the sediment.

4.1 Grain size analysis

Sand that is deposited on the beach originates from two different sources: the erosion of the land which is then brought to the sea by rivers, and from biogenic sources like animal skeletons from the sea and sea cliffs. Apart from this, the beach sand also contains heavy minerals from different sources due to erosion and weathering. The grain size of the beach is very important as it determines the porosity, permeability and penetrability of the sand. The porosity of the sand affects the moisture content and permeability of the sand. Generally, finer sand has greater porosity and can hold more water than coarse sand. Penetrability of the sand is important for burrowing fauna (macro and megafauna), and the water content of the sediment plays a key role in determining their composition. The particle size is according to the Wentworth scale (Table 2) and is classified as phi units, where $\varnothing = -\log_2$ diameter (mm). The classification is given in Table 2 (alongside).

The granulometric analysis of the sediments can be done by running the raw data through softwares available on the web. One such user-friendly software is GRADISTAT (Grain size analysis software) (Copyright Simon Blott 2000)\(^1\).

\(^1\) Copyright Simon Blott 2000. Department of Geology, Royal Holloway University of London, UK (http://scape.brandonu.ca/download/gradistat.zip)

Procedure

Pre-treatment:

1. Take the sample by coning and quartering.

2. Weigh 20g and place in a beaker.

3. Add water to wet the sample. Add 10% HCL (10ml at a time) till all the shells are removed. Warm, cool, decant the acid and wash (twice) with water.

4. Add 6 vol H₂O₂ (15ml), warm, cool and decant acid. Wash (twice) with water.

5. Add saturated solution of oxalic acid (15ml) and aluminum foil.

6. Heat, cool and wash with water.

7. Dry in an oven at 60°C.

Sieving:

Requirements: Ro-tap sieve shaker and a set of sieves.
Divide sieves in 3 sets: ASTM No. 18 to 30, 35 to 70 and 80 to 230.

Pass the sample through the 35 to 70 set. Shake in the sieve shaker for 10mins. Weigh sediment fractions retained in different sieves. If the fraction in 35 sieve exceeds 10% of the total sample, then that has to be passed through the 18 to 30 set. If a considerable quantity of sand is retained in the pan (bottom non porous plate), pass it through 80 to 230 set.
<table>
<thead>
<tr>
<th>Grain size Ø</th>
<th>Sieve No. ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>18</td>
</tr>
<tr>
<td>0.25</td>
<td>20</td>
</tr>
<tr>
<td>0.50</td>
<td>25</td>
</tr>
<tr>
<td>0.75</td>
<td>30</td>
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<tr>
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<td>35</td>
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<td>1.25</td>
<td>40</td>
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<td>3.75</td>
<td>200</td>
</tr>
<tr>
<td>4.00</td>
<td>230</td>
</tr>
</tbody>
</table>

**Calculations:**

- Initial weight of sediment sample
- Total weight before sieving
- Total weight after sieving
- Amount of organic, calcareous and other ferrogenous matter
4.2 Total Organic Carbon

Total Organic Carbon (TOC) in the sediment acts as a source of food for these infaunal species and also limits their distribution. Organic carbon in the sand samples can be determined using the titration method by Wakeel & Riley (1957). For analysing large numbers of samples (100 or more), the expenses incurred could be quite high (due to the volume of reagents required). After experimenting with the methods, we were able to arrive at a modified protocol which allowed reduction of the quantity of reagents required (normality remaining constant) for titration, without compromising on the accuracy of the test.

We propose that for analysing large quantities of samples, the volume of all the chemicals can be reduced to one tenth of what is proposed in the standard methodology by Wakeel & Riley (1957). But care should be taken that 1.5 grams of the sample is used and that it is thoroughly ground in a clean pestle and mortar before the analysis.

4.3 Other abiotic and biotic parameters

Sediment cores of 2.5 cm diameter, up to a depth of 20 cm are used for collecting sand/sediment samples for grain size analysis and measurement of organic carbon. The cores should be collected along both transects at high, mid and low tide levels. In-situ measurements for temperature, electrical conductivity and moisture content can be done using a soil probe. Water samples should also be collected at each site to measure the pH, TDS and electrical conductivity. The sediment samples for sand texture and organic carbon need to be sun dried prior to analysis.
Principle:
The soil is digested with potassium dichromate solution and sulphuric acid making use of the heat of dilution of sulphuric acid. The excess of potassium dichromate not reduced by the organic matter of the soil is determined by titration with standard ferrous ammonium sulphate or ferrous ammonium sulphate solution.

Reagents:
1) Postassium dichromate (1 N): Dissolve 49gm of potassium dichromate in water and make it to 1 litre.
2) Sulphuric acid + silver sulphate: Dissolve 25gm of silver sulphate in 1 liter of conc. Sulphuric acid.
3) Phosphoric acid (85%)
4) Diphenylamine indicator solution: Dissolve 0.5gm of diphenylamine in a mixture of 100ml sulphuric acid and 20ml water and store in a coloured bottle.
5) Ferrous ammonium sulphate (N/2): Dissolve 196gm of A.R. grade ferrous ammonium sulphate in water. Add 20ml sulphuric acid and dilute to 1 litre.

Procedure:
Take 0.5-2g of soil (0.5mm sieved) in a (500ml) conical flask. Add 10ml of 1 N potassium dichromate and 20ml conc. Sulphuric acid. Shake well for a minute or two, and allow it to stand for about 30 minutes. Add 200ml water, 10ml phosphoric acid and 1ml diphenylamine indicator solution. A deep violet colour will appear. Titrate with N/2 ferrous ammonium sulphate solution, till the violet colour changes to blue and finally to green. In the same way carry out a blank determination and calculate the results as follows.

Calculations:
- Weight of soil taken = W g
- Volume of 0.5N ferrous ammonium sulphate required for reducing 10ml Potassium dichromate solution = X ml
- Volume of 0.5N ferrous ammonium sulphate required for reducing the excess of dichromate (experimental reading) = Y ml
- Difference = (X – Y) ml

\[
1\text{ml of 1N Potassium dichromate} = 0.003\text{g carbon}
\]
\[
\% \text{ of C in soil} = \frac{(X - Y) \times N \times 0.003 \times 100}{W}
\]
(Where N = normality of ferrous ammonium sulphate)
Table 3. A list of other biotic and abiotic parameters that influence benthic soft bottom communities

<table>
<thead>
<tr>
<th>S. No</th>
<th>Parameter to be assessed</th>
<th>Importance</th>
<th>Details</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Moisture</td>
<td>Moisture content in the soil is important for the survival of burrowing forms. The moisture content also depends on the grain size of the sediment.</td>
<td>Moisture of the sand where the sample is collected</td>
<td>Soil probe</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>pH ranging from 6.5 to 8.2 is optimum for aquatic organisms. Acidity or alkalinity of the sand depends on the elements present in it (carbonates, silicates phosphates, etc)</td>
<td>Sediment or sand needs to be mixed thoroughly in seawater from the site and the pH measured</td>
<td>pH pen, probes</td>
</tr>
<tr>
<td>3</td>
<td>Dissolved Oxygen</td>
<td>The amount of dissolved oxygen present in the water is important for all living forms. A minimum of 5.0mg/l is required.</td>
<td>Dissolved oxygen levels in seawater</td>
<td>D.O. meter</td>
</tr>
<tr>
<td>4</td>
<td>Salinity</td>
<td>The salinity of seawater is about 35ppt and is mainly due to the presence of dissolved sodium and chloride ions in the water. The shift in the salinity could lead to the organisms being stressed, and in extreme cases could even lead to death.</td>
<td>Salinity of seawater from the site to be measured</td>
<td>Refractometer, salinometer</td>
</tr>
<tr>
<td>5</td>
<td>Total Dissolved Solids (TDS)</td>
<td>The main sources are agricultural run off, and water from industrial and sewage treatment plant.</td>
<td>TDS of seawater to be measured</td>
<td>Conductivity meter/ TDS meter</td>
</tr>
<tr>
<td>6</td>
<td>Turbidity</td>
<td>It is caused by the suspension of mud, clay, algae, bacteria and silica. It decreases the penetration of light to the bottom and affects the health of photosynthetic organisms.</td>
<td>Total suspended solids in the seawater to be measured</td>
<td>Secchi disc/turbidimeter</td>
</tr>
<tr>
<td>S. No</td>
<td>Parameter to be assessed</td>
<td>Importance</td>
<td>Details</td>
<td>Method</td>
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<td>-------</td>
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</tr>
<tr>
<td>7</td>
<td>Heavy Metals</td>
<td>Heavy metal content in the water is mainly due to industrial effluents. The degree of heavy metals in animal tissue depends on the mode of feeding (filter or deposit feeders) especially in benthic forms.</td>
<td>Both in animal tissue and in the water column</td>
<td>Lab analysis</td>
</tr>
<tr>
<td>8</td>
<td>Phytoplankton*</td>
<td>Signify productivity of the region and are a source of food for filter/ suspension feeders.</td>
<td>Water sample collected from the subsurface</td>
<td>Phytoplankton net</td>
</tr>
<tr>
<td>9</td>
<td>Zooplankton*</td>
<td>Signify productivity in the region as they feed on phytoplankton and are also food for filter feeders.</td>
<td>Water sample collected from the water column</td>
<td>Zooplankton net</td>
</tr>
</tbody>
</table>

* Biotic parameters


Our Post-Tsunami Environment Initiative publications:

Beyond the Tsunami: Social, Ecological and Policy Analyses of Coastal and Marine Systems on the Mainland Coast of India

Trends and Patterns in Hydrology and Water Quality in Coastal Ecosystems and Upstream Catchments in Tamil Nadu, India

Macro and Mega Faunal Communities of Intertidal Ecosystems on the Tamil Nadu Coast, India

Status of Fisheries in Tamil Nadu, India: A Snapshot of Present and Long-term Trends

Environmental Law Guide - An Analytical Guide for Deciphering Content of Laws in India

Community Perceptions of Resources, Policy and Development, Post-Tsunami Interventions and Community Institutions in Tamil Nadu, India

Current Status of Mangroves in Kerala and Tamil Nadu, India, with regard to Vegetation, Community Perceptions and Policy

Coastal Sand Dunes of Tamil Nadu, India - An Overview

A Protocol for Ecological Monitoring of Sandy Beaches and Intertidal Fauna on the Indian Coast

Sand in my Hands! An Activity Book on Sandy Beaches and Sand Dunes for Children

Policy Brief: Bioshields

Policy Brief: Sand Dunes

Policy Brief: Sea Walls
The Coastal and Marine Programme (CMP) at the Ashoka Trust for Research in Ecology and the Environment (ATREE) undertook a United Nations Development Programme (UNDP) funded programme called the Post-Tsunami Environment Initiative (PTEI) in collaboration with Nature Conservation Foundation (NCF), Citizen consumer and civic Action Group (CAG) and Foundation for Ecological Research, Advocacy and Learning (FERAL).

In the manual, we provide general information on the classification of beaches and their characteristics, detailed methods of profiling beaches, methods of sampling intertidal sandy shores, and identifying general groups of fauna that are frequently encountered during sampling. We also provide information on monitoring of biotic and abiotic indicators. The purpose of this material is to serve as a manual for resource managers and for researchers doing baseline surveys in monitoring sandy beaches.