Studies on rehabilitation of coral communities and setting up of artificial reefs in Sindhudurg coast, Maharashtra

Deliverable - 4

(Progress report up to 30.11.2017)

Submitted to

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By

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Contents

1. Introduction

The reef ecosystem is the most diversified and complex marine ecosystem and their associated marine life are one of the greatest natural treasures. This ecosystem provides humans with various benefits including food from reef fish, recreation for tourists and coastal protection. This fragile ecosystem are affected by naturally occurring perturbations and in contrast to that, the anthropogenic disturbances are more likely to results in long-lasting or to cause permanent change to the environment. The impacts on reef ecosystem ultimately affect the fisher folk who depend on this ecosystem for daily livelihood. In order to save and to rehabilitate this ecosystem, effective management practices should be implemented for preservation, protection and sustainable utilization.

Considering importance in biodiversity and livelihood, the project titled "Studies on rehabilitation of coral communities and setting up of artificial reefs in Sindhudurg coast, Maharashtra" has been sanctioned by UNDP Sindhudurg Project. The project is implemented by SuganthiDevadason Marine Research Institute (SDMRI), Tuticorin in collaboration with Bombay Natural History Society, Mumbai. The large-scale culture and transplantation of corals could be considered in the degraded areas as an effective management practice for conservation of this valuable ecosystem. SDMRI has standardized the technique and is carrying out coral rehabilitation in Gulf of Mannar, Tamil nadu successfully over a decade with the support of Ministry of Environment, Forests and Climate Change and Tamil Nadu Forest Department. Over 5 Km2 degraded coral area in Gulf of Mananr has already been rehabilitated successfully.

The Sindhudurg Coastal and Marine Ecosystem (SCME), located on the west coast of India (Maharashtra) is one of the 11 ecologically and economically critical habitats identified along the Indian coast. Critical habitats include: rocky shore, sandy shore, rocky island, estuaries, mud flats, marshy land, mangroves, coral reefs, and sargassum forests. There are 367 species of marine flora and fauna reported from the area which include 73 species of marine algae, 18 species of mangroves, 11 species of coral, 300+ species of molluscs, 47 species each of Polychaetes and arthropods, 18 species of sea anemones and 74 species of fishes. Globally

significant species include Whale Shark, Indo-pacific Humpback dolphins, Olive Ridley, Green and Leatherback turtles, and corals.

The primary objectives of coral restoration and artificial reefs are to improve (i) reef quality in terms of live coral cover, (ii) biodiversity and fish resources and (iii) topographic complexity.

Benefits of Coral rehabilitation

- To support natural recruitment process.
- To restore / increase reef cover, particularly in the degraded area - coastal protection & livelihood through fishery production.
- To conserve and enhance threatened / endangered coral species.

Benefits of Artificial Reefs

- Protection of natural ecosystem.
- Fisheries enhancement.
- Coastal conservation.
- Fishery management.

2. Objectives of the project

- To rehabilitate the coral degraded sites by transplantation of coral fragments using artificial substrates and native coral species
- To develop habitats for fish production and enhance biological diversity, in particular fishery resources through artificial reefs
- To provide sustained fishing option to small scale fishermen
- To train the local staff / community in coral rehabilitation work and monitoring
- To encourage ecotourism in artificial reef sites

3. Proposed project activities

- Site selection for coral rehabilitation and artificial reef
- Collection of baseline data (physical, chemical and biological including fish population) in the selected site
- Selection of coral donor site/s for collection of fragments for transplantation
- Construction, transportation and deployment of suitable substrates for artificial reefs and coral transplantation
- Coral transplantation on the substrates
- Preparation of coral transplantation protocol
- Preparation of monitoring protocol
- Monitoring of rehabilitated site and collection of data (survival, growth, flora & fauna assemblage, fish population, plankton density, natural recruitment)
- Training local staff / community in coral rehabilitation and monitoring

4. Total area for coral rehabilitation & Artificial Reef Deployment

Coral Rehabilitation - 0.25 sq.km.
Artificial Reefs - 1.0 sq.km.

5. Site selection to carry out coral rehabilitation and artificial reef activities

Sites outside Malvan Marine Sanctuary

Initially sites have been selected outside declared protected area (Malvan Marine Sanctuary) and baseline data was also collected and report has already been submitted.

However, the opposition from the local people made to shift the sites for coral rehabilitation, artificial reef deployment and donor site within the Malvan Marine Sanctuary. Necessary permission was obtained from Forest Department for the said activities within the Malvan Marine Sanctuary (Annexure 1). Fig.1 shows the present sites where coral rehabilitation (TR), artificial reef deployment (AR) and donor site.

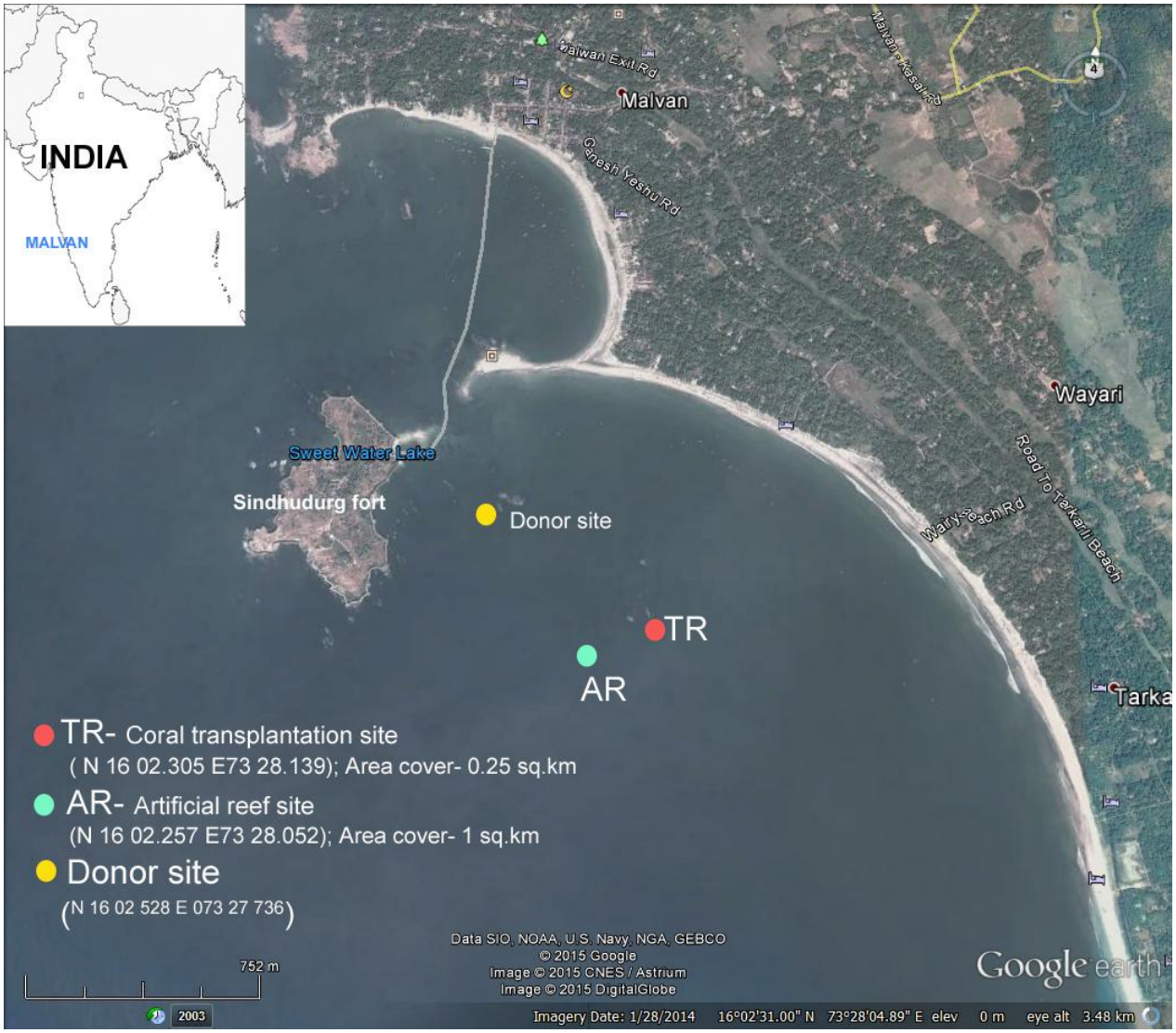


Fig.1: Map showing the sites within Malvan Marine Sanctuary for coral rehabilitation, artificial reef deployment and donor site (TR - Coral Rehabilitation; AR - Artificial Reef Deployment)

6. Baseline data collection in the Final Sites for Coral Rehabilitation, Artificial Reef Deployment and Donor Coral Site within Malvan Marine Sanctuary

The baseline data has been collected during December 2015 at the suitable sites for coral rehabilitation, donor colony collection and artificial reefs deployment within Malvan Marine Sanctuary, prior to start of coral rehabilitation and artificial reef deployment work..

6.1. Materials and methods

Physico-chemical parameters

Seawater temperatures were measured using a standard digital thermometer. Salinity was determined using refracto meter. Seawater pH was measured soon after collection by using pre-calibrated digital pH-meter. Turbidity was measured using Elico water quality analyzer. Total Suspended Solids (TSS) was measured by filtering a known volume of sample through a pre-weighed 0.45µ Whatman glass fibre filter paper (GF/C) using a Millipore filtering system. Dissolved oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were analyzed by following Strickland and Parsons method (1972). Analyses of calcium (Ca), magnesium (Mg) and chlorides were done titrimetrically. Nitrates (NO_3) and nitrites (NO_2) were measured spectrophotometrically by following the method of Strickland and Parson (1972). Total coliform bacteria were measured using MPN method.

Sediment samples were collected from all the sites using Van Veen Grab sampler. Sediment pH was measured using pH meter. Oil and grease in sediment was analysed using separating funnel method. Organic matter in sediment was estimated by the method described by El Wakeel and Riley (1956). Phytoplankton and zoo plankton samples were collected from the surface water at all the stations. For the quantitative estimation, a Sedgewick Rafter Counting Cell was used. The sediment samples pre stained with Rose Bengal were sieved through 1 mm and 63µ mesh sieves by adding copious amount of water for separating macro and meio benthic fauna respectively. The organisms retained in the sieves were preserved in 5% formalin and were identified using standard manuals. Heavy metals such as lead, nickel, cadmium, chromium and mercury in the water samples and heavy metals such as manganese, lead, nickel, cadmium, chromium and mercury in the sediment samples were analysed using Atomic Absorption Spectrophotometer (AAS).

Coral assessment

The percentage cover of corals and other sessile benthic categories were assessed by Line Intercept Transect (LIT) method following English *et al.*, (1997). The survey started with

mapping of reef areas, using manta tow technique (Done *et al.*, 1982). The assessment involved SCUBA diving. Depending on the size of the reefs, 5 to 10 transects were laid on each locations. The percentage cover of each life form category, percentage of bleaching and disease prevalence was calculated following the method of English *et al.*, (1997).

Life form categories and codes

CATEGORIES	**CODE**	**NOTES / REMARKS**
Dead Coral	DC	recently dead, white to dirty white
Dead Coral with Algae	DCA	this coral is standing, skeletal structure can still be seen
Acropora Branching	ACB	at least 2° branching, e.g. *Acropora palmate*, *A.formosa*
Encrusting	ACE	usually the base-plate of immature *Acropora* forms, e.g. *A. palifera* and *A. cuneata*
Sub massive	ACS	robust with knob or wedge-like form e.g. *A. palifera*
Digitate	ACD	no least 2° branching, typically includes *A. humilis*, *A. digitifera* and *A. gemmifera*
Tabular	ACT	horizontal flattened plates e.g. *A. hyacinthus*
Non – Acropora Branching	CB	at least 2° branching e.g. *Seriatopora hystrix*
Encrusting	CE	major portion attached to substratum as a laminar plate e.g. *Porites vaughani*, *Montipora undata*
Foliose	CF	Coral attached at one or more points, leaf-like, or plate-like appearance e.g. *Merulina ampliata*, *Montipora aequituberculata*
Submassive	CS	tends to form small columns, knobs, or wedges e.g. *Porites lichen*, *Psammocora digitata*
Mushroom	CMR	solitary, free-living corals of the *Fungia*
Heliopora	CHL	blue coral
Millepora	CME	fire coral
Tubipora	CTU	organ-pipe coral, *Tubipora musica*
Other Fauna:		
Soft Coral	SC	soft bodied coral
Sponge	SP	
Zoanthids	ZO	examples are *Platythoa*, *Protopalythoa*
Others	OT	Ascidians, anemones, gorgonians, giant clams etc.
Algae Algal Assemblage	AA	consists of more than one species
Coralline Algae	CA	

	Halimeda	HA	
	Macroalgae	MA	weedy/fleshy browns, reds, etc.
	Turf Algae	TA	lush filamentous algae, often found inside damselfish territories
Abiotic	Sand	S	
	Rubble	R	unconsolidated coral fragments
	Silt	SI	
	Water	WA	fissures deeper than 50 cm
	Rock	RCK	
Other		DDD	Missing data

Visual census fish population

Fish density and diversity was assessed by visual census applying Belt Transect method (English et al., 1997).

6.2. Results

6.2.1. Donor site

GPS	**Depth**	**Visibility**
16^0 02. 528" N 073^0 27. 736" E	3 - 5 meters	<3 meter

Donor site was mostly rocky in nature with corals and seaweeds which is surrounded by sandy bottom. Depth ranged between 3 and 5 and the visibility was about 3 m.

Live coral cover in the donor site was 29.1% and sand was the dominant category with 38.2% followed by rock with 23.4% while algae covered about 9.2%. *Turbinaria* was the dominant genus with 20±2 no.m^{-2} followed by *Cyphastrea* with 19.7±3.2 no.m^{-2}. Other genera found were *Pavona* (0.7±0.6 no.m^{-2}), *Coscinarea* (9±1 no.m^{-2}), *Platygura* (4.7±2.3 no.m^{-2}), *Goniastrea* (9±3 no.m^{-2}), *Favites* (9.3±2.1 no.m^{-2}), *Favia* (5±4.6 no.m^{-2}), *Leptastrea* (0.3±0.6 no.m^{-2}), *Echinopora* (8.7±2.5 no.m^{-2}), *Goniopora* (8.7±2.1 no.m^{-2}) and *Porites* (8.3±2.5 no.m^{-2}). Totally 8 species of fishes were observed and most of which were reef fishes dominated by

Leiognathus sp. (36±7 50no.m^{-2}) and *Chaetodon collare* (32±2 50no.m^{-2}). Overall density of fishes was 147±13.5 50no.m^{-2}.

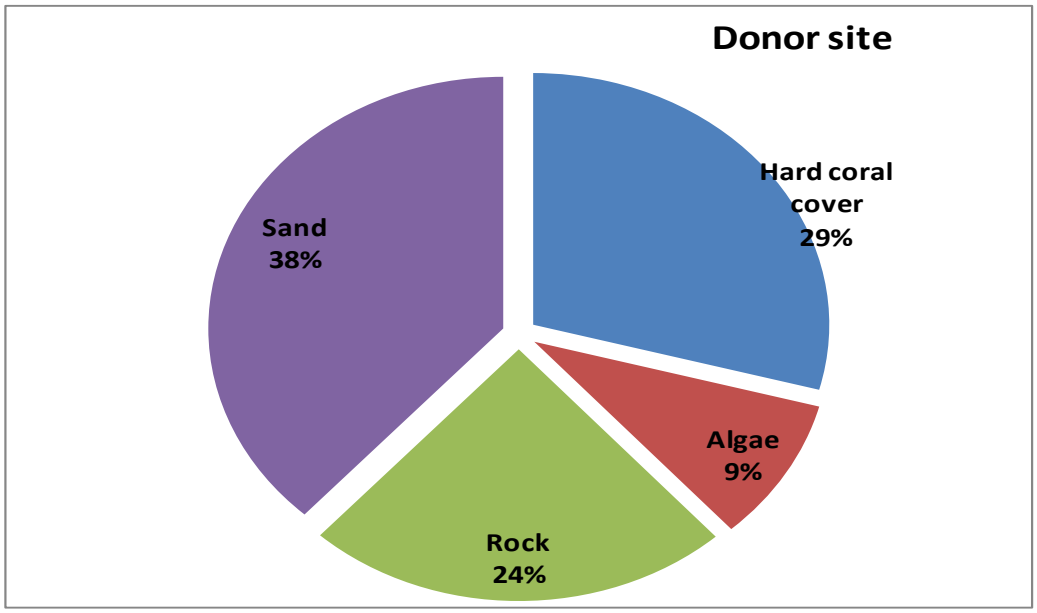


Fig. 2 Percent cover of benthic community in donor site

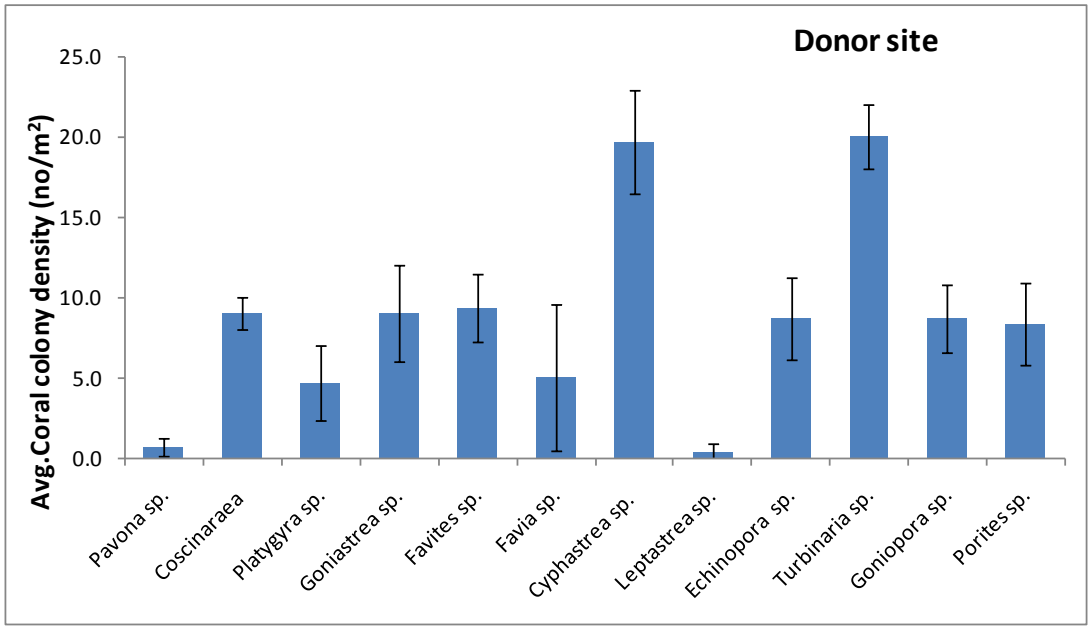


Fig.3: Coral density in donor site

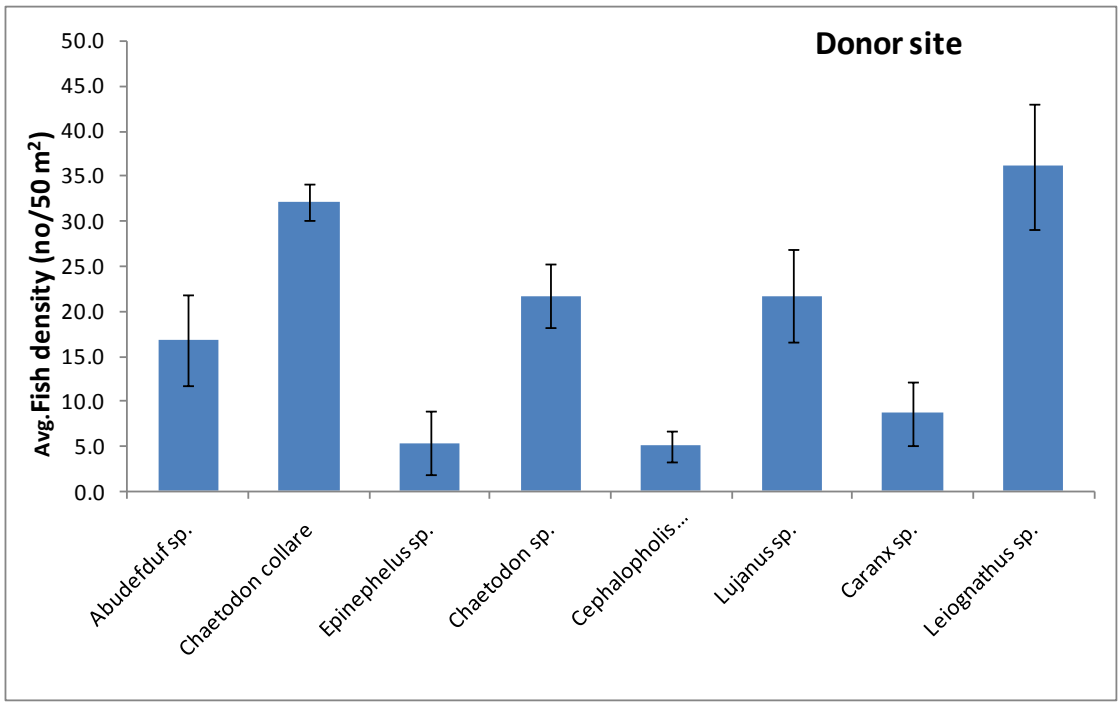


Fig. 4: Fish abundance in donor site

At donor site, among the physical parameters, water temperature was 29.4 and 29.5°C respectively in surface and bottom waters; salinity was 35 ppt in both the surface and bottom waters; EC was 31.1 and 30.9 mS/cm respectively; turbidity was 4.6 and 4.2 NTU respectively; pH was 7.98 in both the surface and bottom waters; TSS (Total Suspended Solids) was 110 and 126 mg/l respectively. Among the chemical parameters, DO (Dissolved Oxygen) was 4.6 and 4.4 mg/l respectively in surface and bottom waters; COD (Chemical Oxygen Demand) was 1.4 and 1.39 mg/l; BOD (Biological Oxygen Demand) was 1.6 and 1.5 mg/l respectively; calcium level was 410 and 420 mg/l respectively; magnesium level was 1169 and 1179 mg/l respectively; nitrate level was 1.14 and 1.16 µg/l respectively; nitrite level was 0.42 and 0.41 µg/l respectively; chloride level was around 17.2 g/l in both the surface and bottom waters respectively; oil and grease level was 0.11 and 0.09 mg/l respectively.

Among the biological parameters, phytoplankton density was 168.3 cells/l; zooplankton density was 148965 no/m^3. Among the benthic categories in the sediment samples, gastropods and bivalves were dominant with 54 and 36 no.m^{-2} respectively while the densities of polychaetes, echinoderms and crustaceans were 28, 19 and 21 no.m^{-2}.

Observed coral list:

1. *Pavona varians*
2. *Coscinaraea monile*
3. *Platygyra* sp.
4. *Goniastrea retiformis*
5. *Favites abdita*
6. *Favites flexuosa*
7. *Favia* sp.
8. *Cyphastrea microphthalma*
9. *Leptastrea* sp.
10. *Echinopora* sp.
11. *Turbinaria mesenterina*
12. *Goniopora minor*
13. *Porites* sp.

Table 1: Physio- chemical and biological assessment in donor site

Physical parameters		
	Surface	**Bottom**
Temperature (^{0}C)	29.4	29.5
Salinity (ppt)	35	35
EC (mS/cm)	31.1	30.9
Turbidity (NTU)	4.6	4.2
pH Value	7.98	7.98
TSS (mg/l)	110	126
Chemical parameters		
Do (Dissolved oxygen)	4.6	4.4
COD (mg/l)	1.4	1.39
BOD (mg/l)	1.6	1.5
Calcium (mg/l)	410	420
Magnesium (mg/l)	1169	1179

Nitrates (µg at/l)	1.14	1.16
Nitrites (µg at/l)	0.42	0.41
Chloride (g/l)	17.2	17.2
Oil & grease (mg/l)	0.11	0.09
Plankton density		
Phytoplankton (cells/l)	168.3	
Zooplankton (no/m^3)	148965	
Benthos (no/m^2)		
Gastropods		54
Bivalves		36
Polychaetes		28
Echinoderms		19
Crustaceans		21

6.2.2. Artificial Reef Deployment site

GPS	**Depth**	**Visibility**
16^0 02. 257" N 073^0 28. 052" E	8 meters	<3 meter

AR site was mostly sandy in nature with dispersed rocks. Depth of the site was around 8 m. Sand was the dominant category with 84.2% followed by rock with 11.7% while algae were 4.2%. Live corals were not observed in this site.

Totally 7 species of fishes were observed and the dominant fish species was *Abudefduf* sp. with 9±1 50no.m^{-2} followed by *Lutjanus* sp. with 8±2.6 50no.m^{-2}. Total density of the fishes in this site was 36±3.6 50no.m^{-2}.

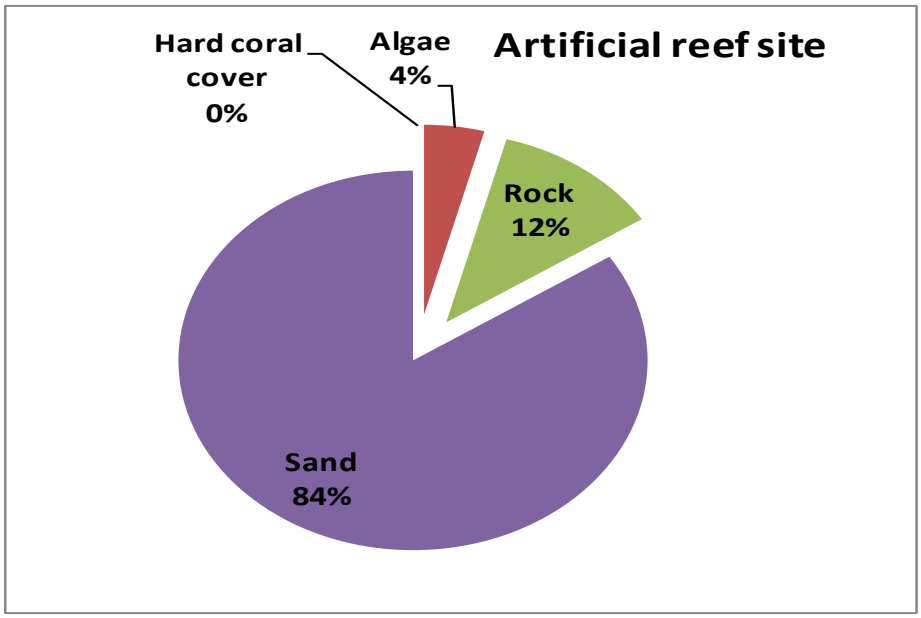


Fig. 5 Percent cover of benthic community in AR site

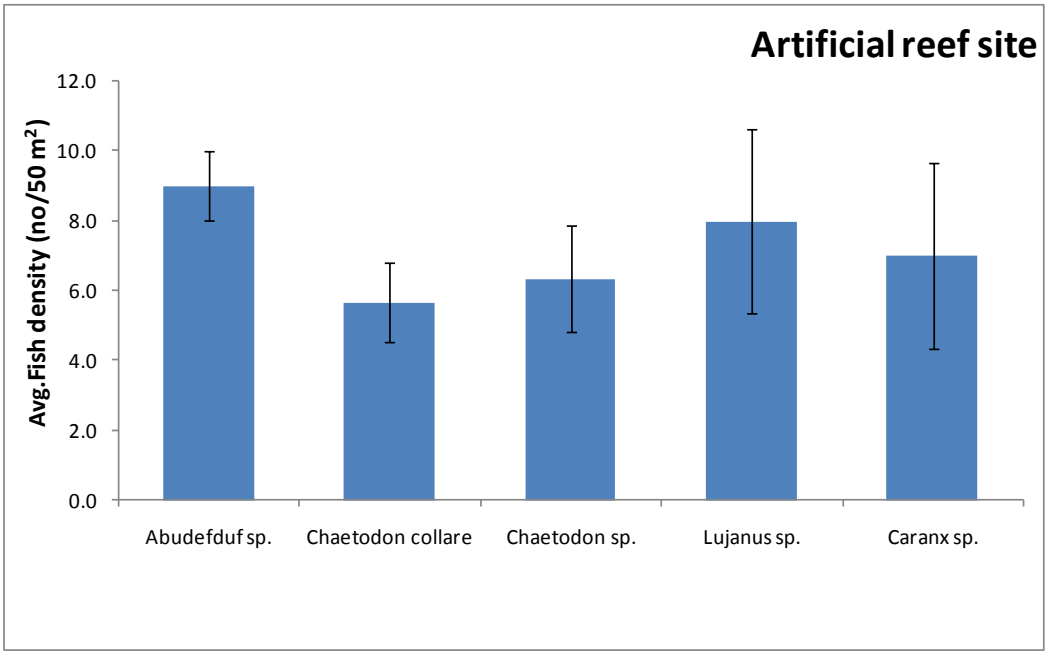


Fig. 6: Fish density from AR site

At AR site, among the physical parameters water temperature was 29.4 °C in both surface and bottom waters; salinity was around 36 ppt; EC was 31.5 and 31.2 mS/cm respectively in surface and bottom waters; turbidity was 4.7 and 4.9 NTU respectively; pH was 7.99 in both surface and bottom waters; TSS (Total Suspended Solids) was 119 and 121 mg/l respectively.

Among the chemical parameters, DO (Dissolved Oxygen) was 4.3 and 4.4 mg/l respectively in surface and bottom waters; COD (Chemical Oxygen Demand) was 1.23 and 1.26 mg/l respectively; BOD (Biological Oxygen Demand) was 1.7 and 1.6 mg/l respectively; calcium level was 425 and 430 mg/l respectively; magnesium level was 1168 and 1134 mg/l respectively; nitrate level was 1.19 and 1.21 µg/l respectively; nitrite level was 0.39 and 0.36 µg/l respectively; chloride level was 17.5 and 17.6 g/l respectively; oil and grease level was 0.16 and 1.13 mg/l respectively.

Among the biological parameters, phytoplankton density was 175.2 cells/l; zooplankton density was 133548 no/m^3. Among the benthic categories in the sediment samples, gastropods and bivalve were dominant with 42 and 34 no.m^{-2} respectively while the densities of polychaetes, echinoderms and crustaceans were 21, 26 and 31 no.m^{-2}.

Table 2: Physio- chemical and biological assessment in AR site

Physical parameters		
	Surface	**Bottom**
Temperature (^{0}C)	29.4	29.4
Salinity (ppt)	36	36
EC (mS/cm)	31.5	31.2
Turbidity (NTU)	4.7	4.9
pH Value	7.99	7.99
TSS (mg/l)	119	121
Chemical parameters		
Do (Dissolved oxygen)	4.3	4.4
COD (mg/l)	1.23	1.26
BOD (mg/l)	1.7	1.6
Calcium (mg/l)	425	430
Magnesium (mg/l)	1168	1134
Nitrates (µg at/l)	1.19	1.21
Nitrites (µg at/l)	0.39	0.36
Chloride (g/l)	17.5	17.6

Oil & grease (mg/l)	0.16	1.13
Plankton density		
Phytoplankton (cells/l)	175.2	
Zooplankton (no/m^3)	133548	
Benthos (no/m^2)		
Gastropods		42
Bivalves		34
Polychaetes		21
Echinoderms		26
Crustaceans		31

6.2.3. Coral rehabilitation site

GPS	**Depth**	**Visibility**
16^0 02305" N 073^0 28. 139" E	5 meters	<3 meter

Transplantation site was mostly rocky in nature with occasional coral patches and seaweeds which is surrounded by sandy bottom. Depth of the site was around 5m and visibility was about 3m. Transplantation site had a little amount of live corals with 3.6%. Sand was the dominant benthic category with 69.8% followed by rock with 20.6% while algae were 6%. Only three coral genera were observed in this site which are *Favites* (3.3±1.5 no.m^{-2}), *Cyphastrea* (1.3±0.6 no.m^{-2}) and *Turbinaria* (5±2 no.m^{-2}). Totally 4 species of fishes were observed with a total density of 23±2 50no.m^{-2} which was dominated by *Lutjanus* sp.(7.75±1.5 50no.m^{-2}) and *Chaetodon* sp. (6±1 50no.m^{-2}).

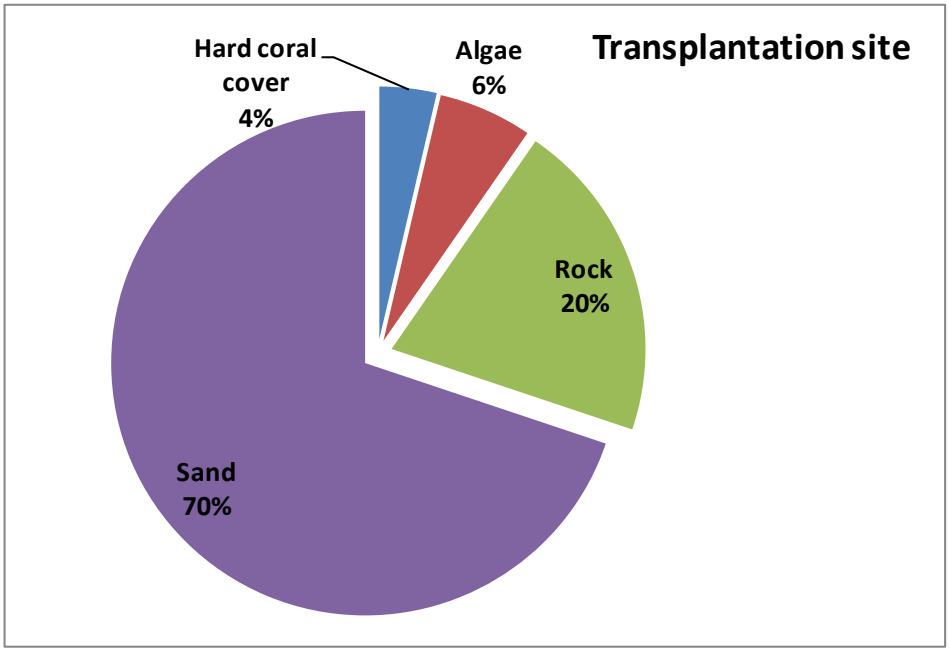


Fig. 2 Percent cover of benthic community in Transplantation site

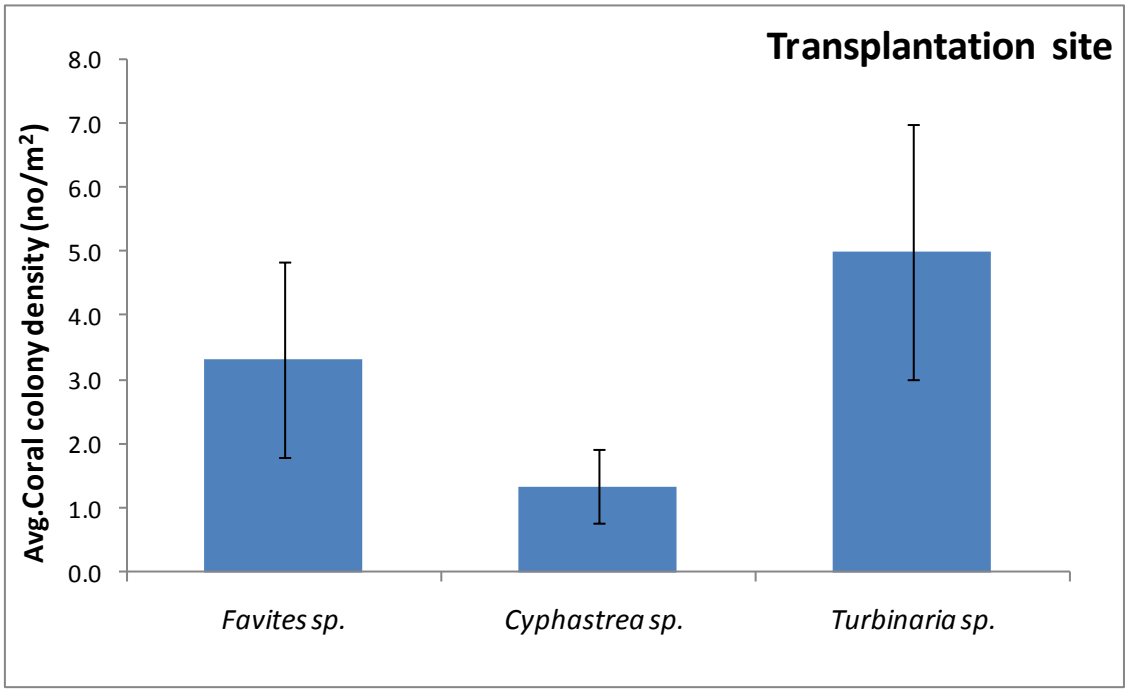


Fig. 3: Coral density in rehabilitation site

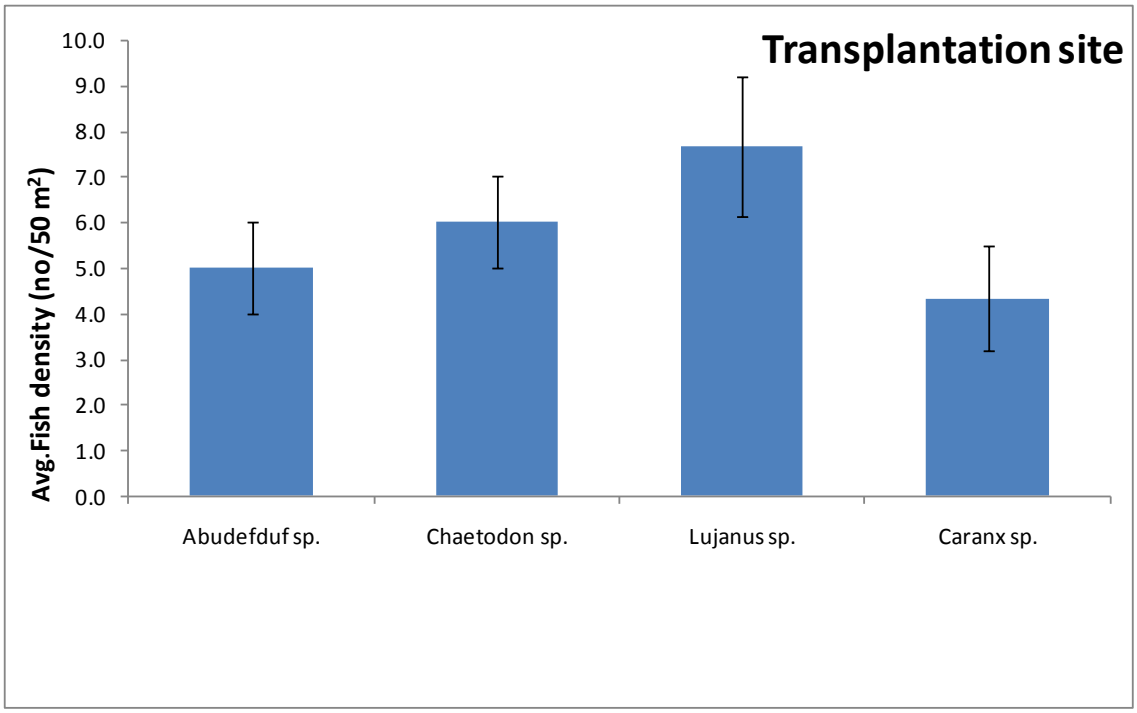


Fig. 4 Fish density in rehabilitation site

At transplantation site, among the physical parameters water temperature was 29.4 and 29.3°C respectively in surface and bottom waters; salinity was around 36 ppt in both surface and bottom waters; EC was 31.2 and 31.3 mS/cm respectively; turbidity was 4.4 and 4.5 NTU respectively; pH was 7.98 in both surface and bottom waters; TSS (Total Suspended Solids) was 134 and 129 mg/l respectively. Among the chemical parameters, DO (Dissolved Oxygen) was 4.5 and 4.6 mg/l respectively in surface and bottom waters; COD (Chemical Oxygen Demand) was 1.52 and 1.5 mg/l respectively; BOD (Biological Oxygen Demand) was 1.5 and 1.3 mg/l respectively; calcium level was 431 and 426 mg/l respectively; magnesium level was 1134 and 1148 mg/l respectively; nitrate level was 1.16 and 1.13 µg/l respectively; nitrite level was 0.41 and 0.43 µg/l respectively; chloride level was 17.6 and 17.5 g/l respectively; oil and grease level was 0.12 and 0.16 mg/l respectively.

Among the biological parameters, phytoplankton density was 175.26 cells/l; zooplankton density was 134248 no/m^3. Among the benthic categories in the sediment samples, gastropods and bivalves were dominant with 31 and 24 no.m^{-2} respectively while the densities of polychaetes, echinoderms and crustaceans were 13, 9 and 17 no.m^{-2}.

Table 3: Physio- chemical and biological assessment in Transplantation site

Physical parameters		
	Surface	**Bottom**
Temperature (^{0}C)	29.4	29.3
Salinity (ppt)	36	36
EC (mS/cm)	31.2	31.3
Turbidity (NTU)	4.4	4.5
pH Value	7.98	7.98
TSS (mg/l)	134	129
Chemical parameters		
Do (Dissolved oxygen)	4.5	4.6
COD (mg/l)	1.52	1.5
BOD (mg/l)	1.5	1.3
Calcium (mg/l)	431	426
Magnesium (mg/l)	1134	1148
Nitrates (µg at/l)	1.16	1.13
Nitrites (µg at/l)	0.41	0.43
Chloride (g/l)	17.6	17.5
Oil & grease (mg/l)	0.12	0.16
Plankton density		
Phytoplankton (cells/l)	175.26	
Zooplankton (no/m^3)	134248	
Benthos (no/m^2)		
Gastropods		31
Bivalves		24
Polychaetes		13
Echinoderms		9
Crustaceans		17

Observed coral list:

1. *Favites abdita*
2. *Favites flexuosa*
3. *Cyphastrea microphthalma*
4. *Turbinaria mesenterina*

6.3. Baseline data - Executive Summary

Baseline data collection on donor site, AR site and transplation was done during December 2015. Donor site was mostly rocky in nature with corals and seaweeds which is surrounded by sandy bottom. Depth ranged between 3 and 5 and the visibility was about 3 m. Live coral cover in the donor site was 29.1% and sand was the dominant category with 38.2% followed by rock with 23.4%. *Turbinaria* was the dominant genus with 20±2 no.m^{-2} followed by *Cyphastrea* with 19.7±3.2 no.m^{-2}. Totally 8 species of fishes dominated by *Leiognathus* sp. (36±7 50no.m^{-2}) and *Chaetodon collare* (32±2 50no.m^{-2}).

AR site was mostly sandy in nature with dispersed rocks. Depth of the site was around 8 m. Sand was the dominant category with 84.2% followed by rock with 11.7%. Totally 7 species of fishes were observed and the dominant fish species was *Abudefduf* sp. with 9±1 50no.m^{-2} followed by *Lutjanus* sp. with 8±2.6 50no.m^{-2}.

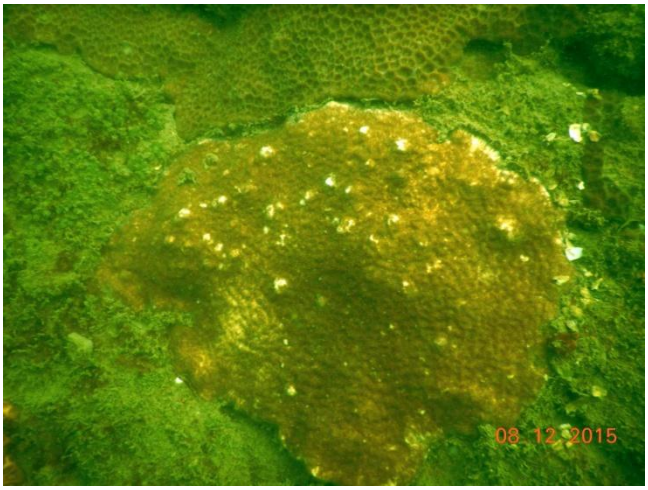
Transplantation site was mostly rocky in nature with occasional coral patches and seaweeds which is surrounded by sandy bottom and depth of the site was around 5m. Live coral cover was 3.6% ini the transplantation site. Sand was the dominant benthic category with 69.8% followed by rock with 20.6%. Totally 4 species of fishes were observed dominated by by *Lutjanus* sp.(7.75±1.5 50no.m^{-2}) and *Chaetodon* sp. (6±1 50no.m^{-2}).

Baseline data in Malvan Marine Sanctuary - underwater photographs of coral species


11.12.2015


08.12.2015


11.12.2015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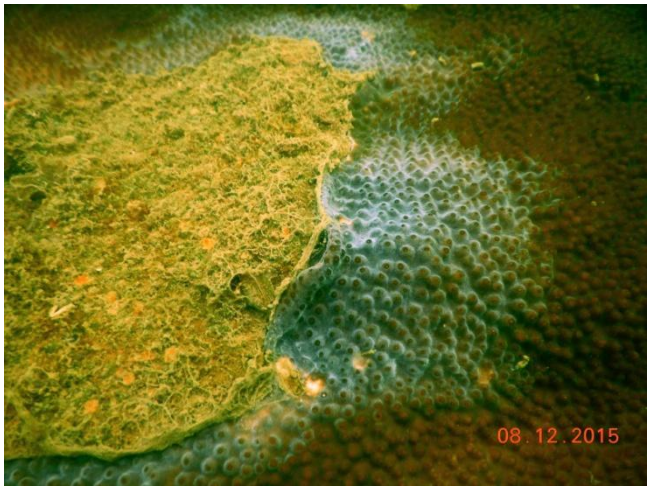
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7. Coral Bleaching Assessment in Malvan Marine Sanctuary during Dec. 2015

7.1. Executive summary

- *The assessment in Malvan Marine Sanctuary in the Arabian Sea during 08-12 December 2015 revealed that there is a severe coral bleaching*
- *All the four surveyed coral sites were observed with bleached corals.*
- *Benthic community structure is dominated by corals with 35.07±3.34%; but among the total live coral cover, 27.65±3.26% was observed bleached and only 7.42±0.33% were found healthy*
- *Rock, sand and algae were other benthic categories with an average cover of 24.97±2.81, 29.36±4.7 and 10.59±2.08% respectively.*
- *The results of belt transects showed that the intensity of bleaching was very severe with an average prevalence of 85.49±0.62% while the healthy coral cover was 14.51±0.62%.*
- *In total, 11 coral genera were found bleached which are Pavona, Coscinaraea, Goniastrea, Favites, Favia, Cyphastrea, Leptastrea, Montastrea, Turbinaria, Goniopora and Porites.*
- *The genus Turbinaria was found to be resistant among the observed coral genera which had very minimal bleaching.*
- *Water temperature was recorded between 29.4 and 29.8°C in all the study sites and the elevated water temperature is the reason for this bleaching.*
- *Other environmental parameters such as salinity, pH, total suspended solids and dissolved oxygen were within the optimum levels.*
- *The US National Oceanic & Atmospheric Administration (NOAA) and International Society for Reef Studies (ISRS) have already announced officially this bleaching as third global bleaching event during 2015-16, triggered by El Nino.*

7.2. Introduction

The Malvan Marine Sanctuary in Maharashtra has a reasonable coral distribution in the west coast of India. The coast of Malvan is marked by islands, rocky areas and sandy beaches. Qasim and Wafar (1979) reported 8 genera of corals in this region and there are no significant survey, assessment and monitoring of corals since then. Furthermore, there is no baseline information about the extent and diversity of corals in Malvan Marine Sanctuary.

Corals are sensitive to temperature fluctuations and can survive in temperatures between 24 and 29° C. When the temperature exceeds this level, the corals tend to bleach (whitening). This whitening happens because the corals lose their symbiotic unicellular algae called zooxanthellae as Zooxanthellae give colour to the corals. Such a bleaching event was noticed in Malvan Marine Sanctuary because of elevated sea surface temperature. It has been already announced officially by the US National Oceanic & Atmospheric Administration (NOAA) and International Society for Reef Studies (ISRS) that third global bleaching event is happening during 2015-16, triggered by El Nino.

The present assessment was carried out in Malvan Marine Sanctuary during 08-12 December 2015 while doing the substrate deployment works and donor coral colony survey for the coral rehabilitation under the UNDP-GEF funded project on *"Coral restoration and artificial reef deployment to increase the live coral cover and to enhance the fishery resources".* The assessment team has researchers from Suganthi Devadason Marine Research Institute, Bombay Natural History Society and UNDP-GEF Sindhudurg project.

As the coral bleaching prevalence was very severe in Malvan Marine Sanctuary, we could not carry out coral transplantation as it is not feasible to do while the corals are under severe stress due to bleaching. However, the team has conducted thorough survey in the reef areas to document the extent of prevalence of coral bleaching in Malvan Marine Sanctuary.

7.3. Methodology

Assessment on coral reefs of Malvan Marine Sanctuary in the Arabian Sea was conducted during 8-12, December 2015. Four different reef sites were assessed inside the Sanctuary and were named as Reef sites 1, 2, 3 and 4. Assessment protocol involved scuba

diving and the initial observation was done by visual assessment. Benthic community structure was assessed with 20 m Line intercept Transects (LIT) (English et al. 1997). Table 1 and Fig.1 give details of all four surveyed reef sites.

Sl.No.	Reef sites	Depth (m)	GPS Coordinates
1.	Reef-1	3.5	N 16^0 02. 528'' E 073^0 27. 736''
2.	Reef-2	3.0	N 16^0 02 .22'' E 073^0 27. 422''
3.	Reef-3	3.2	N 16^0 02. 378'' E 073^0 27. 704''
4.	Reef-4	4.0	N 16^0 02. 535'' E 073^0 27. 893''

Table 1: Details of study sites

Three transects were laid in each reef site and the direction of transects was parallel to the Sindudhurg Fort. Using LIT method, percentages of healthy live coral cover, bleached live coral cover, algae, rock and sand were calculated.

20 m belt transects (English *et al.*, 1997) were laid parallel to the reefs to assess the specific prevalence of coral bleaching in each site. Three belt transects were laid in each reef site and each transect covered an area measuring 20 X 2 m (2 m on each side of the transect line) and 20 m distance was given between each transect. Physico-chemical parameters such as temperature, salinity, pH, Total Suspended Solids (TSS) and Dissolved Oxygen (DO) were measured. Water temperature was measured using digital thermometer; salinity using refractometer; pH using pH paper; TSS by filtering a known volume of sample through a pre-weighed 0.45µ Whatman glass fibre filter paper; and dissolved oxygen using Strickland and Parsons (1972) method.

Fig.1: Map showing the four study sites in Malvan Marine Sanctuary

7.4. Observations

Overall bleaching

Benthic community structure in Malvan coast is dominated by live corals with an average of 35.07±3.34%. Among the total live coral cover, only 7.42±0.33% were healthy and 27.65±3.26% were found bleached. Rock and sand were the other dominant categories with 24.97±2.81 and 29.36±4.7% respectively while algae were 10.59±2.08%. The results of belt transects showed that the intensity of bleaching was very severe with an average prevalence of 85.49±0.62 while the healthy coral cover was 14.51±0.62 (Figs.2 and 3).

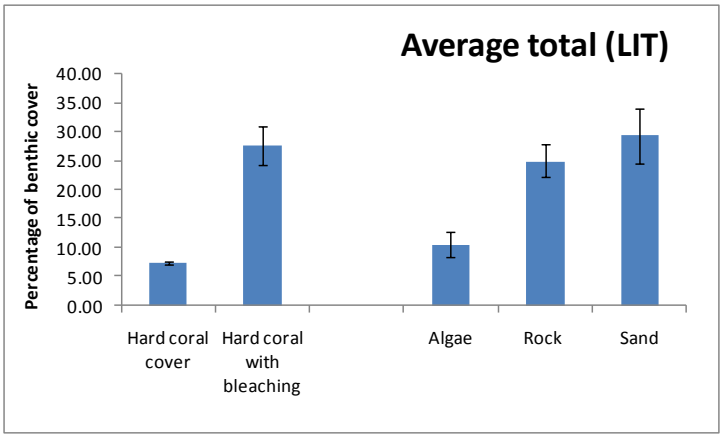

Fig. 2: Overall percent cover of benthic community in Malvan Marine Sanctuary

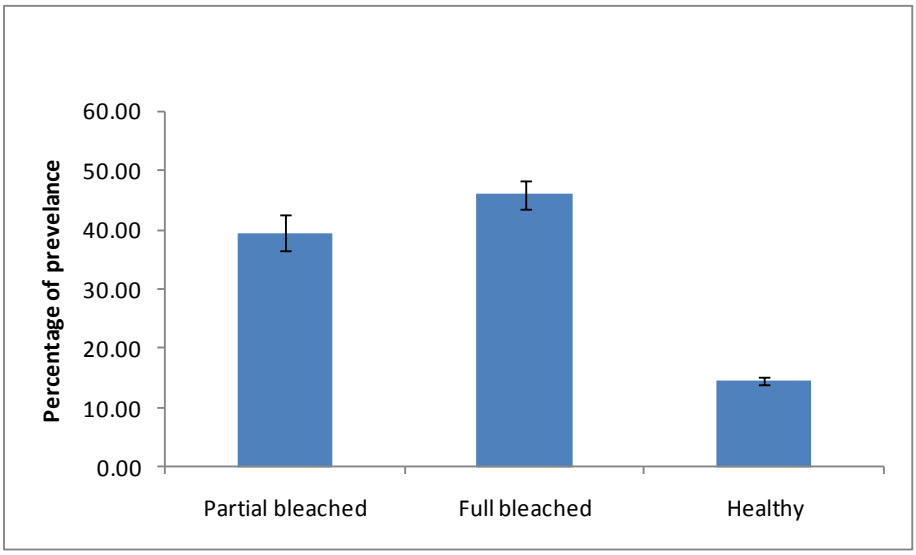

Fig. 3: Overall coral bleaching prevalence in Malvan Marine Sanctuary

Benthic community structure

Reef site 1

At reef site 1, healthy live coral cover was 8.14±0.49% and bleached live coral cover was 35.65±1.78%. Algae, rock and sand were observed 8.49±1.02, 17.94±1.54 and 29.78±0.24% respectively.

Reef site 2

At reef site 2, healthy live coral cover was 6.84±0.42% and bleached live coral cover was 26.81±3.16%. Algae, rock and sand were observed 16.68±1.20, 30.62±0.53 and 19.04±4.14% respectively.

Reef site 3

At reef site 3, healthy live coral cover was 6.9±0.85% and bleached live coral cover was 28.38±2.24%. Algae, rock and sand were observed 9.68±0.65, 28.13±2.28 and 26.91±4.30% respectively.

Reef site 4

At reef site 4, healthy live coral cover was 7.81±0.63% and bleached live coral cover was 19.76±1.71%. Algae, rock and sand were observed 7.52±0.68, 23.20±0.97 and 41.71±1.16% respectively.

Table 2 gives the percent cover of benthic community in Malvan Marine Sanctuary.

	Hard coral cover	**Hard coral with bleaching**	**Algae**	**Rock**	**Sand**
Reef 1	8.14	35.65	8.49	17.94	29.78
Reef 2	6.84	26.81	16.68	30.62	19.04
Reef 3	6.90	28.38	9.68	28.13	26.91
Reef 4	7.81	19.76	7.52	23.20	41.71

Table 2: Percent cover of benthic community in Malvan Marine Sanctuary

Prevalence of coral bleaching

Reef site 1

At reef site 1, average prevalence of coral bleaching was 72.33±0.90% and among this 41.79±2.95% of corals was completely bleached and 30.54±3.39% were found partially bleached while the prevalence of healthy corals was 22.59±3.59% (Fig.4).

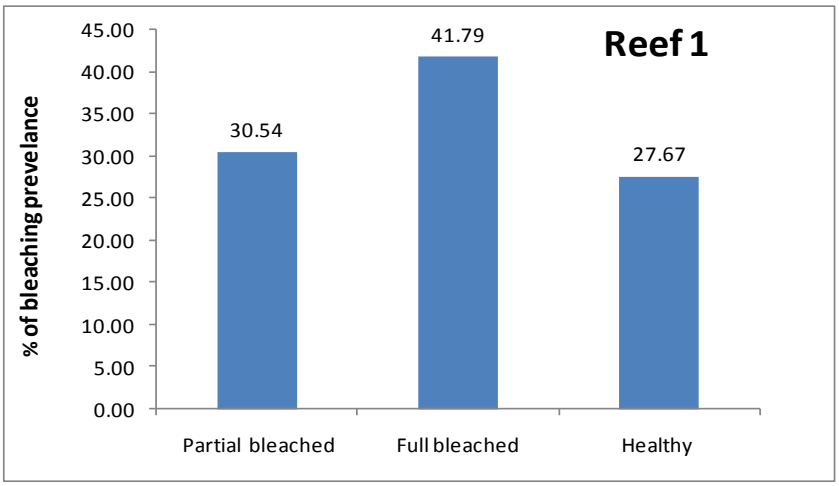

Fig. 4: Coral bleaching prevalence in Reef site - 1

In total, 11 genera of corals were observed at reef site 1. Among them, the proportion of partially bleached, completely bleached and healthy is as follows. *Pavona* (n=13): partially

bleached 51.11%, completely bleached 42.22% and healthy 6.67%; *Coscinaraea* (n=14): partially bleached 50%, completely bleached 50% and healthy 0%; *Goniastrea* (n=23): partially bleached 26.94%, completely bleached 70.03% and healthy 3.03%; *Favites* (n=17): partially bleached 34.17%, completely bleached 55% and healthy 10.83%; *Favia* (n=8): partially bleached 22.22%, completely bleached 77.78% and 0%; *Cyphastrea* (n=27): partially bleached 28.74%, completely bleached 58.97% and healthy 12.29%; *Leptastrea* (n=8): partially bleached 41.67%, completely bleached 41.67% and healthy 16.67%; *Montastrea* (n=13): partially bleached 52.78%, completely bleached 41.67% and healthy 5.56%; *Turbinaria* (n=49): partially bleached 6.41%, completely bleached 1.96% and healthy 91.63%; *Goniopora* (n=18): partially bleached 33.33%, completely bleached 51.85% and healthy 14.81%; *Porites* (n=15): partially bleached 34.52%, completely bleached 60.71% and healthy 4.76% (Table 3).

	Partial bleached	**Full bleached**	**Healthy**
Pavona sp.	51.11	42.22	6.67
Coscinaraea sp.	50.00	50.00	0.00
Goniastrea sp.	26.94	70.03	3.03
Favites sp.	34.17	55.00	10.83
Favia sp.	22.22	77.78	0.00
Cyphastrea sp.	28.74	58.97	12.29
Leptastrea sp.	41.67	41.67	16.67
Montastrea sp.	52.78	41.67	5.56
Turbinaria sp.	6.41	1.96	91.63
Goniopora sp.	33.33	51.85	14.81
Porites sp.	34.52	60.71	4.76

Table 3: Coral bleaching prevalence in Reef site - 1

Reef site 2

At reef site 2, average prevalence of coral bleaching was 65.55±3.07% and among this 35.98±4.49% of corals was completely bleached and 29.58±2.12% were found partially bleached while the prevalence of healthy corals was 34.45±3.07% (Fig.5).

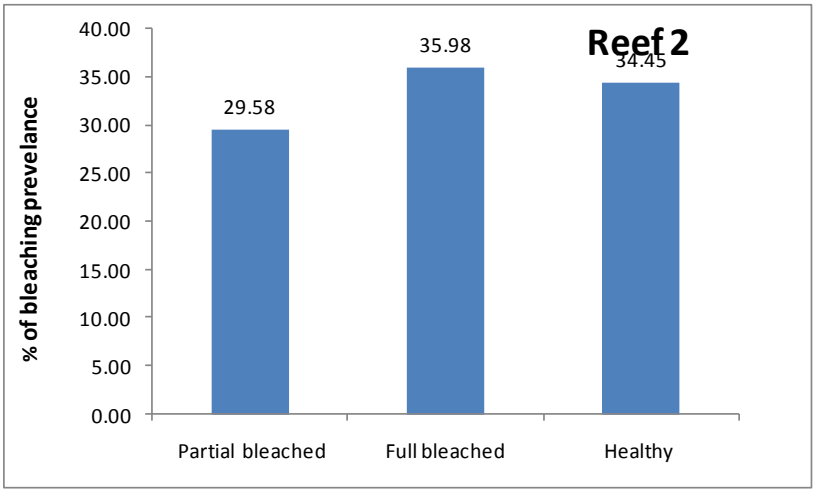

Fig. 5: Coral bleaching prevalence in Reef site - 2

In total, 8 genera of corals were observed at reef site 2. Among them, the proportion of partially bleached, completely bleached and healthy is as follows. *Coscinaraea* (n=19): partially bleached 45.56%, completely bleached 54.44% and healthy 0%; *Goniastrea* (n=13): partially bleached 42.22%, completely bleached 41.11% and healthy 16.67%; *Favites* (n=13): partially bleached 25.40%, completely bleached 74.6% and healthy 0%; *Favia* (n=12): partially bleached 24.44%, completely bleached 70% and 5.56%; *Cyphastrea* (n=22): partially bleached 40.57%, completely bleached 42.76% and healthy 16.67%; *Montastrea* (n=8): partially bleached 38.89%, completely bleached 52.78% and healthy 8.33%; *Turbinaria* (n=66): partially bleached 14.89%, completely bleached 4.65% and healthy 80.46%; *Porites* (n=16): partially bleached 41.11%, completely bleached 58.89% and healthy 0% (Table 4).

	Partial bleached	**Full bleached**	**Healthy**
Coscinaraea sp.	45.56	54.44	0.00
*Goniastre*a sp.	42.22	41.11	16.67
Favites sp.	25.40	74.60	0.00
Favia sp.	24.44	70.00	5.56
Cyphastrea sp.	40.57	42.76	16.67
Montastrea sp.	38.89	52.78	8.33
Turbinaria sp.	14.89	4.65	80.46
Porites sp.	41.11	58.89	0.00

Table 4: Coral bleaching prevalence in Reef site - 2

Reef site 3

At reef site 3, average prevalence of coral bleaching was 69.54±1.87% and among this 34.09±0.99% of corals was completely bleached and 34.49±1.33% were found partially bleached while the prevalence of healthy corals was 30.46±1.87% (Fig.6).

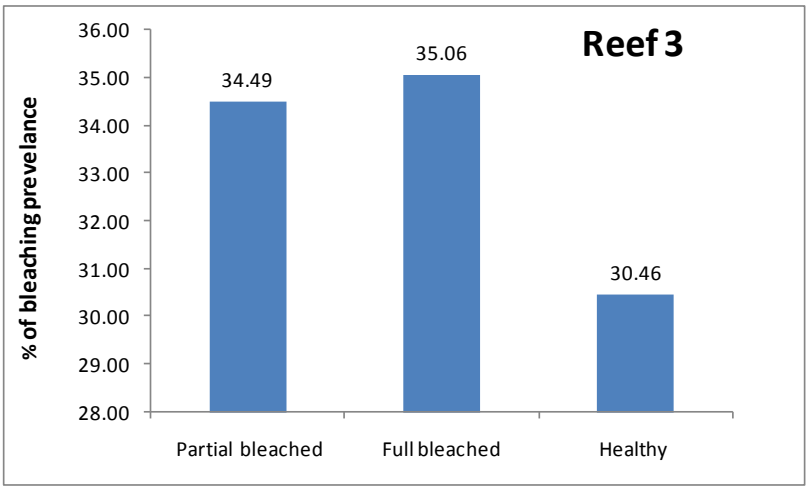

Fig. 6: Coral bleaching prevalence in Reef site - 3

In total, 8 genera of corals were observed at reef site 3. Among them, the proportion of partially bleached, completely bleached and healthy is as follows. *Coscinaraea* (n=16): partially bleached 43.61%, completely bleached 56.39% and healthy 0%; *Goniastrea* (n=21): partially bleached 40.83%, completely bleached 50.83% and healthy 8.33%; *Favites* (n=11): partially bleached 55.56%, completely bleached 44.44% and healthy 0%; *Favia* (n=5): partially bleached 66.67%, completely bleached 33.33% and 0%; *Cyphastrea* (n=19): partially bleached 44.44%, completely bleached 47.22% and healthy 8.33%; *Montastrea* (n=22): partially bleached 64.04%, completely bleached 35.96% and healthy 0%; *Turbinaria* (n=44): partially bleached 4.65%, completely bleached 2.56% and healthy 92.79%; *Porites* (n=7): partially bleached 44.44%, completely bleached 55.56% and healthy 0% (Table 5).

	Partial bleached	**Full bleached**	**Healthy**
Coscinaraea sp.	43.61	56.39	0.00
Goniastrea sp.	40.83	50.83	8.33
Favites sp.	55.56	44.44	0.00

Favia sp.	66.67	33.33	0.00
Cyphastrea sp.	44.44	47.22	8.33
Montastrea sp.	64.04	35.96	0.00
Turbinaria sp.	4.65	2.56	92.79
Porites sp.	44.44	55.56	0.00

Table 5: Coral bleaching prevalence in Reef site - 3

Reef site 4

At reef site 4, average prevalence of coral bleaching was 76.30±3.24% and among this 39.23±3.44% corals was completely bleached and 37.07±3.19% were found partially bleached while the prevalence of healthy corals was 23.70±3.24% (Fig.7).

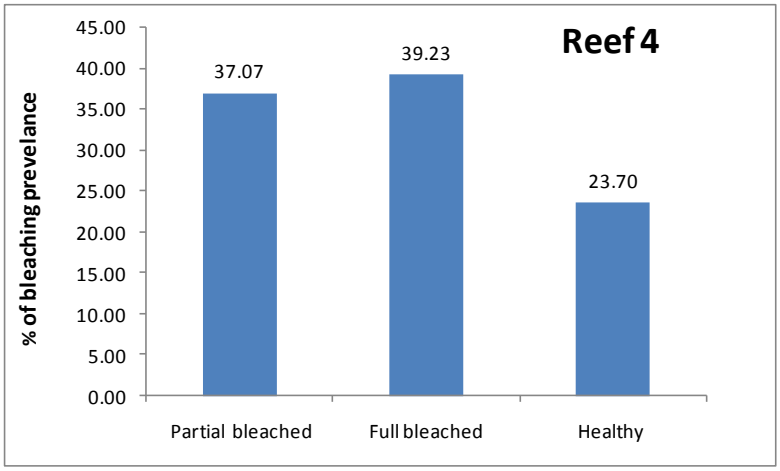

Fig. 7: Coral bleaching prevalence in Reef site - 4

In total, 9 genera of corals were observed at reef site 4. Among them, the proportion of partially bleached, completely bleached and healthy is as follows. *Coscinaraea* (n=16): partially bleached 25%, completely bleached 58.33% and healthy 16.67%; *Goniastrea* (n=12): partially bleached 36.11%, completely bleached 55.56% and healthy 8.33%; *Favites* (n=11): partially bleached 38.89%, completely bleached 55.56% and healthy 5.56%; *Favia* (n=8): partially bleached 61.11%, completely bleached 38.89% and healthy 0%; *Cyphastrea* (n=16): partially bleached 43.61%, completely bleached 56.39% and healthy 0%; *Montastrea* (n=17): partially bleached 65.19%, completely bleached 28.15% and healthy 6.67%; *Turbinaria* (n=39): partially bleached 18.73%, completely bleached 15.51% and healthy 65.76%; *Goniopora* (n=14): partially

bleached 64.44%, completely bleached 35.56% and healthy 0%; *Porites* (n=7): partially bleached 38.89%, completely bleached 44.44% and healthy 16.67% (Table 6).

	Partial bleached	**Full bleached**	**Healthy**
Coscinaraea sp.	25.00	58.33	16.67
Goniastrea sp.	36.11	55.56	8.33
Favites sp.	38.89	55.56	5.56
Favia sp.	61.11	38.89	0.00
Cyphastrea sp.	43.61	56.39	0.00
Montastrea sp.	65.19	28.15	6.67
Turbinaria sp.	18.73	15.51	65.76
Porites sp.	38.89	44.44	16.67
Goniopora sp.	64.44	35.56	0.00

Table 6: Coral bleaching prevalence in Reef site - 4

Physico-chemical parameters

Surface water temperature was observed between 29.4 and 29.5°C in all the four sites while bottom temperature was between 29.5 and 29.8°C. Salinity was around 35 ppt; pH level was recorded between 7.93 and 7.99; Total Suspended Solids was recorded between 101 and 131 mg/l; and dissolved oxygen content was observed between 4.3 and 4.9 ml/l (Table 7).

	St 1		**St 2**		**St 3**		**St 4**	
Parameters	**Sur**	**Bot**	**Sur**	**Bot**	**Sur**	**Bot**	**Sur**	**Bot**
Temperature (°C)	29.4	29.6	29.4	29.5	29.5	29.8	29.5	29.6
Salinity (ppt)	35	35	35	34	35	35	35	34
pH level	7.99	7.96	7.97	7.93	7.99	7.98	7.96	7.95
Total Suspended Solids (mg/l)	118	123	101	121	105	120	123	131
Dissolved Oxygen Content (ml/l)	4.9	4.5	4.8	4.3	4.9	4.5	4.7	4.3

Table 7: Physico-chemical parameters in Malvan Marine Sanctuary

7.5. Conclusion

Coral bleaching in Malvan Marine Sanctuary in the Arabian Sea is alarming as among the average 35.07% corals, only 7.42% was found to be healthy. Further, bleaching prevalence was as high as 85.49% as opposed to the healthy corals of 14.51%. This coral bleaching is found to be triggered by thermal stress as the water temperature was high between 29.4 and 29.8°C. Corals tend to lose their zooxanthellae and lose their colour in the process when the temperature crosses the optimum level. However, corals will get their zooxanthellae and colour back within three months when the temperature comes back normal. If the elevated temperature persists for more than three months, the corals will die. Considering the intensity of coral bleaching in Malvan, if they do not recover within next two months, there will be significant mortality which will reduce the percentage of live coral cover.

This elevated sea surface temperature in this time of the year is a global phenomenon as coral bleaching has been observed in many countries around the world which is triggered by El Nino. The US National Oceanic & Atmospheric Administration (NOAA) and International Society for Reef Studies (ISRS) have announced this bleaching as third global bleaching event. First and second global coral bleaching events happened during 1998 and 2008 respectively. It has been predicted that 38% global corals and 12,000 sq.km coral reefs will die because of this event.

The elevated sea surface temperature is a global phenomenon. However, anthropogenic threats such as tourism, pollution and fishing in reef areas should be regulated as the corals are already stressed by the temperature. Permanent and regular monitoring of these fragile ecosystems is inevitable to see the trend and to take necessary actions.

Fully bleached corals in Malvan Marine Sanctuary in Dec. 2015


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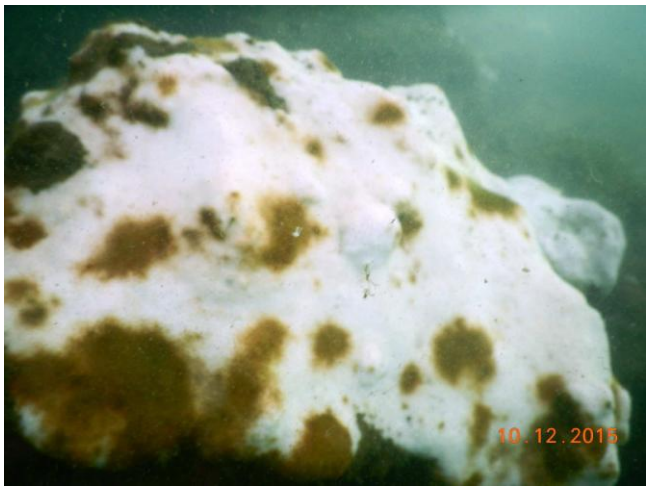
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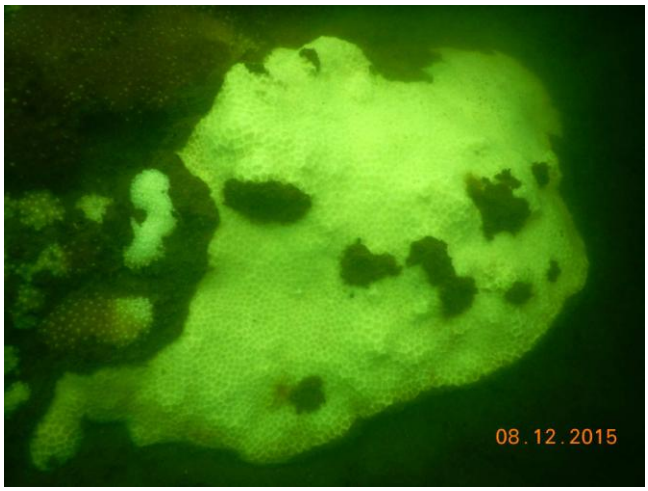
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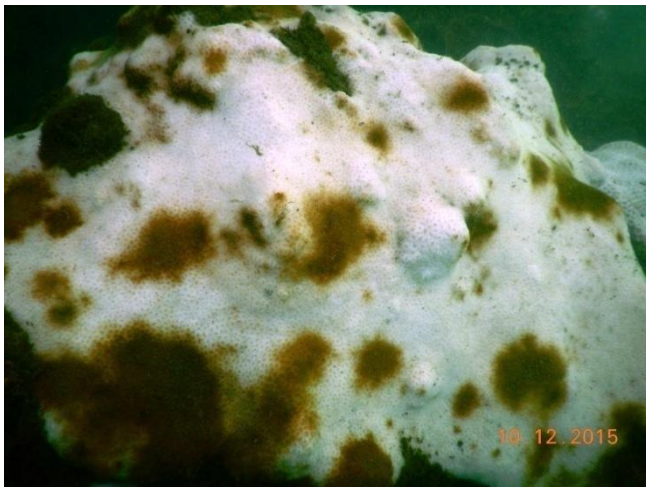
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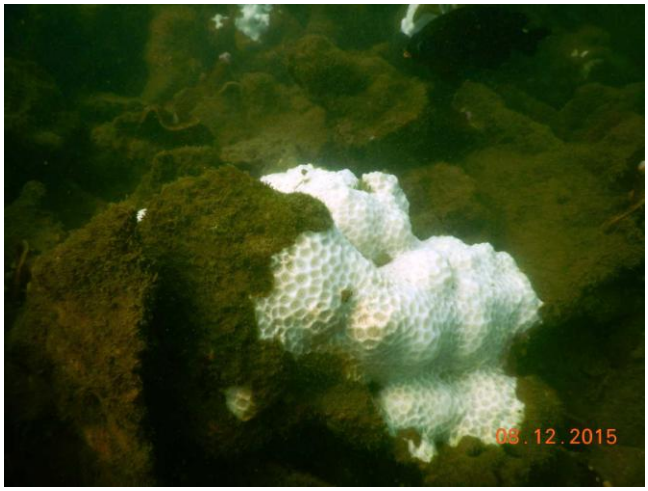
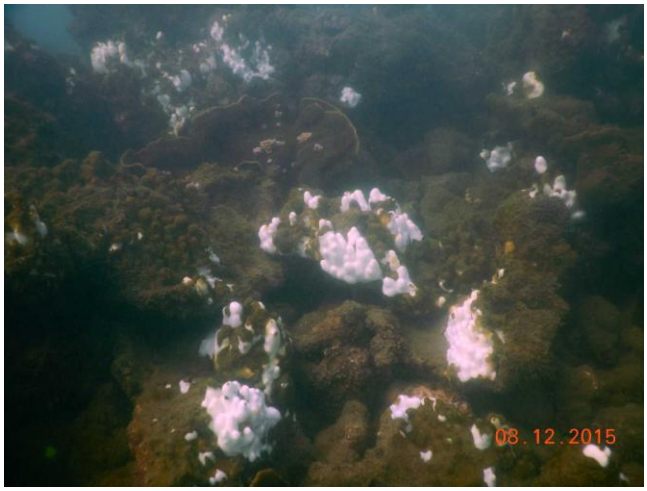
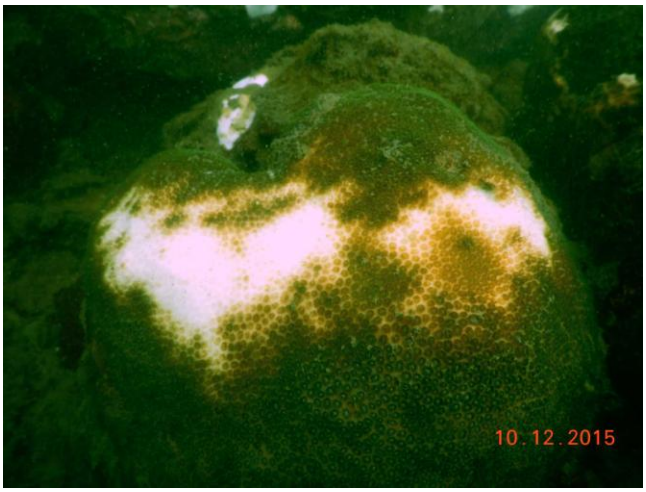
Partially bleached corals in Malvan Marine Sanctuary in Dec. 2015





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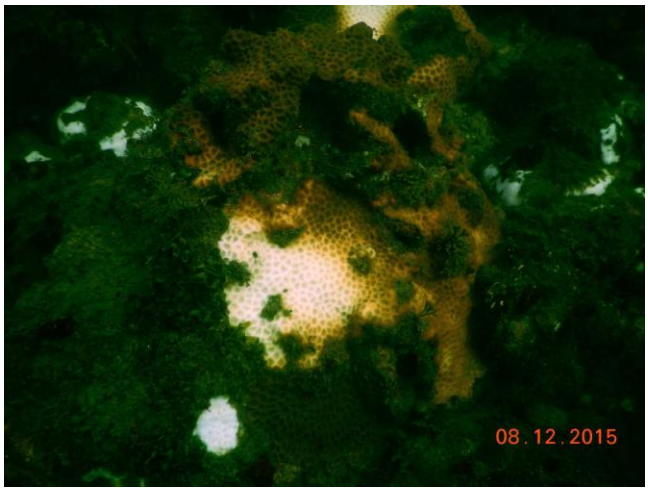
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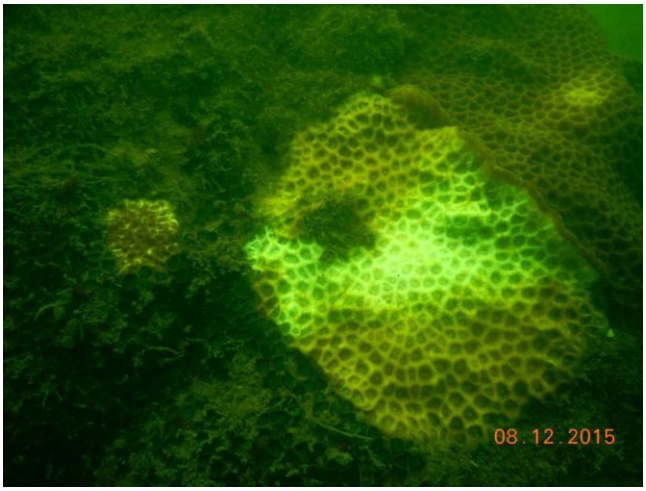
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Healthy corals (*Turbinaria* sp.) in Malvan Marine Sanctuary in Dec. 2015

Other healthy corals in Malvan Marine Sanctuary in Dec. 2015

8. Coral Rehabilitation and Artificial Reef Deployment

8.1. Artificial reef modules

Each artificial reef module is constructed as three separate slabs for easy transportation and deployment. Each slab is 137 x 90 cm in size with 9 holes of two different diameters: 18 and 11 cm. The modules construction is a labour oriented task and 250 modules have been constructed and deployed so far. Artificial reef modules were constructed based on the design standardized by SDMRI. Artificial reef structures are given in the fig.1.

Fig.1: Artificial reef modules

8.2. Coral rehabilitation substrates

Concrete frames of 1m X 1m X 0.25m size were used for coral rehabilitation. Also, cement slabs of 20 cm X 5 cm X 1.5 cm were used for fixing the coral fragments before being placed on the deployed concrete frames. The concrete frames and slabs were constructed using ferro-cement. The concrete frames and slabs were constructed based on the design standardized by SDMRI. Totally 100 concrete frames and 1000 cement slabs have been constructed and deployed so far. Concrete frames are shown in the fig.2.

Fig.2: Concrete frames used as substrate for coral rehabilitation

8.3. Transportation of artificial reef modules and substrates

The artificial reef modules and coral rehabilitation substrates were transported from the place of construction to the shore by tractors during low tides. From the seashore, the modules and substrates were transported to the deployment sites using a floating jetty which can accommodate up to 5 tons. Transportation demands heavy labour work and 8 - 12 paid labours were involved for this. Pictures of transportation are given in the figs. 3 & 4. .

Fig.3: Floating jetty carrying modules

Fig.4: Floating jetty carrying modules and substrates

8.4. Deployment

After transporting the artificial reef slabs to the deployment site with the floating jetty, they were tied together as a triangle module before pushing into the water. Likewise, concrete frames were also pushed into the water from the floating jetty. Each artificial reef module and concrete frame was tied with a floating buoy before putting into the water. After they were put into the water, scuba divers arranges the artificial reef modules and concrete frames underwater in proper order. Cement slabs were not deployed during this phase as they are deployed along with the fragments. The numbers of deployed artificial reef modules and cement frames are given in the table 1. Pictures of deployment of substrates are given in the figs. 5-7.

Fig.5: Deployment of artificial reef modules

Fig.6: Deployment of concrete frames

Fig.7: underwater view of deployment artificial reef modules

Table 1: Details of deployment of artificial reefs and concrete frames

Deployment of Artificial reefs			
Date	**Number of modules**	**Number of trips**	**Total number of modules deployed/ day**
09-12-2015	4	2	8
10-12-2015	8	1	8
11-12-2015	8	2	16
12-12-2015	8	3	24
13-12-2015	8	3	24
14-12-2015	8	3	24

15-12-2015	8	3	24
16-12-2015	8	3	24
17-12-2015	8	3	24
18-12-2015	8	3	24
19-12-2015	8	3	24
20-12-2015	8	3	24
Total			**250**
Deployment of Concrete frames			
10-12-2015	25	3	75
11-12-2015	25	1	25
Total			**100**

8.5. Selection of coral species for transplantation

Coral species selected for restoration was restricted only to *Turbinaria mesenterina* because of the widespread bleaching event in the Malvan coast. *Turbinaria mesenterina* was found to be resistant against the thermal bleaching triggered by El nino.

8.6. Collection, transportation and transplantation

The fragments for coral restoration from *Turbinaria mesenterina* colonies were collected from the selected donor site involving scuba diving. Collection was done using a hammer and chisel under the water. Collected fragments were brought to the boat in plastic trays. Precision and care was taken during fragmentation and transportation of fragments donor the donor site. On the boat, collected fragments were immediately transferred to big plastic tubs with seawater and were given aeration with portable aerators. The plastic tubs with coral fragments were covered by clothes to avoid direct sunlight and were transported immediately to the restoration site. Sea water in the tubs was changed at regular intervals in order to reduce the stress and the level of temperature and salinity were monitored.

Because of the ongoing bleaching event, restoration was done only in 5 concrete frames which include 50 cement slabs. On the restoration site, collected coral fragments of *Turbinaria mesenterina* were further fragmented to desirable size (> 8 cm size) using a bone cutter. Fragments were placed on the cement slabs and were tied firmly using nylon rope. Immediately after that, the fragments tied with the cement slabs are taken into the water in plastic trays by the scuba divers for the transplantation. The slabs with fragments are tied firmly with the already laid concrete frames under the water. Extra care was taken to make sure the tying was strong and the slabs and fragments are intact on the concrete frames. Documentation was done underwater with underwater still and video cameras. Collection and transportation of fragments are given in the figs. 8-9.

Fig.8: Transplantation of coral fragments

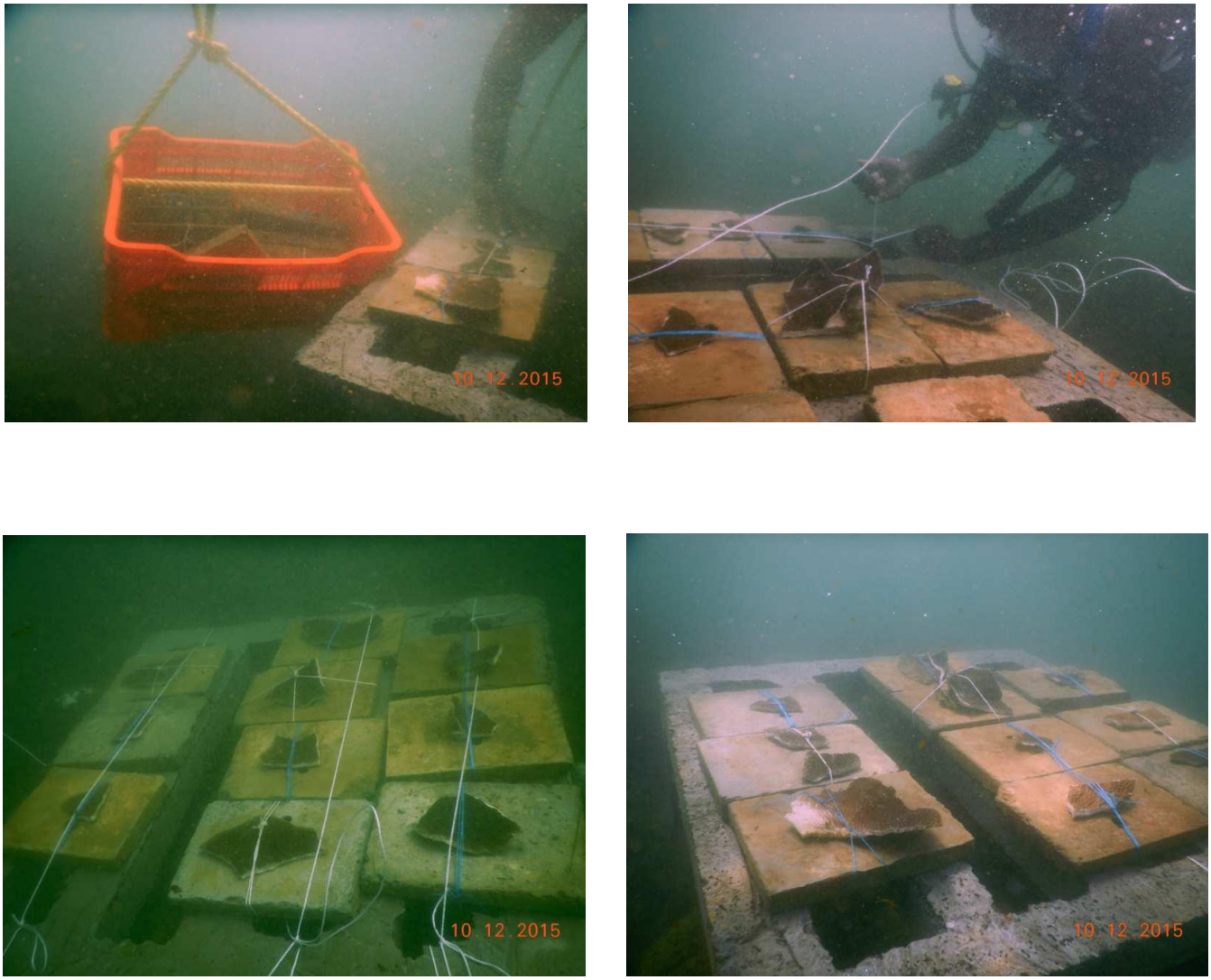

Fig.9: Cement slabs with fragments placed on concrete frames

8.7. Executive summary

A total of 250 artificial reef modules and 100 concrete frames were deployed. Out of100 concrete frames, only five concrete frames were transplanted with 50 coral fragments tied on individual cement slabs due the bleaching event.

Transportation of artificial reef modules and substrates was done during low tides from the construction site with tractors. A floating jetty was used to transport the modules and substrates to the respective selected deployment sites

A severe thermal bleaching was observed in corals of Malvan coast during Dec. 2015 and *Turbinaria mesenterina* was found to be resistant to the bleaching. Hence, coral transplantation was done only in 5 concrete frames (50 fragments) with *Turbinaria mesenterina*.

9. Monitoring

After deployment of artificial reef modules, regular monitoring was conducted. Initial attachment of epifauna and benthic assemblages and accumulation of fish have started as expected. Following photos (Fig.1) show the condition of deployed artificial reef modules.

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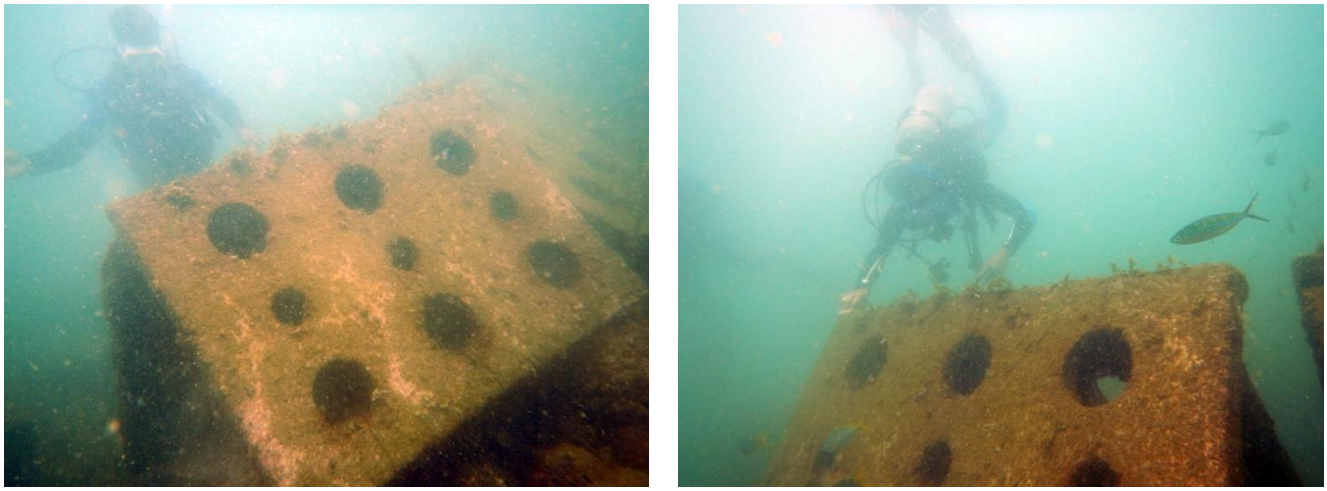

Fig.1: Artificial reef site in March 2016

Regarding coral transplantation, the transplanted fragments were healthy with 100% survival rate. Transplanted fragments have attached onto the substrates and have also started growing (Fig.2).

Fig.2: Transplanted coral fragments in April 2016

Current status of the constructed modules (as on May 2016)

A total of 200 artificial reef modules, 316 concrete frames and 4477 cement slabs have been placed on the beach for making the deployment easier. But after the agitation by local people started, those structures are stranded on the beach and are being damaged by the waves and tides. Following photos (Fig.3 and 4) show the stranded artificial substrates.

Fig.3: Artificial reef modules and concrete substrates kept on the bleach

Fig.4: Cement slabs kept on the beach

10. Selection of New sites for Artificial Reef deployment and Coral Transplantation

List of participants in the field work during March 2017

SDMRI

1. Dr. K. Diraviya Raj, Assistant Professor
2. Dr. G. Mathews, Assistant Professor
3. Mr. M. Selva Bharath, Senior Research Fellow
4. Mr. P. Dinesh Kumar, Senior Research Fellow
5. Mr. A. Arasa Muthu, Senior Research Fellow
6. Mr. A. Sahaya Mani, Field Assistant
7. Mr. N. Stephen, Field Assistant

BNHS

1. Dr. Vishale Bhave, Scientist

UNDP-GEF Sindhudurg Project

1. Mr. Rohit Sawant, Project Staff
2. Ms. Durga Digale (one day during site selection in Vengurla), Project Staff

Date wise filed activity

Date	Work carried out
03.03.17	Assessment on already deployed coral transplantation frames (near Sindhudurg fort), arrangement of frames, removal of algae, monitoring on already transplanted fragments (transplantation site near Sindhudurg fort)
04.03.17	No field work due to the local agitation
05.03.17	Monitoring on already deployed artificial reef modules (AR site near Sindhudurg fort), coral transplantation on 17 concrete frames (170 coral fragments) - transplantation site near Sindhudurg fort
06.03.17	Coral transplantation on 22 concrete frames (220 coral fragments) - transplantation site near Sindhudurg fort.
07.03.17	Site selection and baseline data collection in Shiroda, Vengurla (NEW SITE)
08.03.17	Site selection and baseline data collection in Chivla beach, Malvan (NEW SITE)

10.1. Works completed until September 2016

Coral transplantation

Part of coral transplantation concrete frames was deployed during December 2015. A total of 100 concrete frames were deployed during that time. Because of the El nino triggered bleaching event during December 2015, rehabilitation was done only on five concrete frames which include 50 cement slabs. *Turbinaria mesenterina* was the only transplanted species as it was found resistant to the bleaching event and was healthy. Then, because of the hostility shown by the local fishermen from Malvan, deployment and transplantation were stopped.

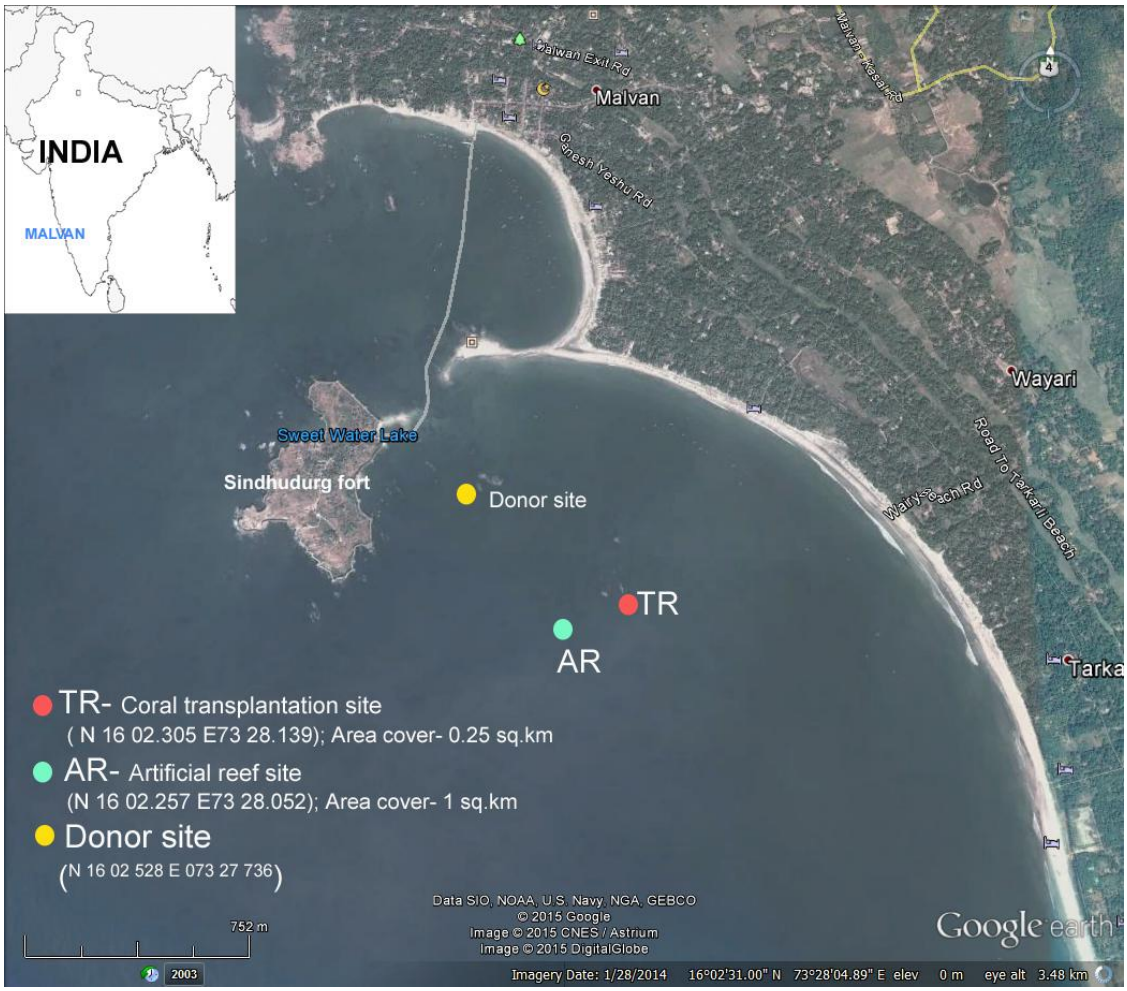

Fig. 1 Map showing the previously deployed study sites at Malvan Marine Sanctuary

Artificial reef deployment

Part of the artificial reef modules were also deployed during December 2015. A total of 250 artificial reef modules were deployed before the agitation started. Since then, because of the agitation caused by the local fisherfolk, further deployment could not be done until March 2017.

Coral bleaching and recovery between December 2015 and May 2016

During December 2015, severe coral bleaching was observed because of the temperature elevation triggered by El nino. Prevalence of coral bleaching was as high as 85.49% and on only14.51% of corals were found healthy during December 2015. However, corals have recovered from bleaching during May 2016. During May 2016, the prevalence of bleaching was only 7.0% and healthy corals were 82.8%. About 10.2% of coral mortality was recorded because of this bleaching. *Turbinaria* was the genus found resistant to coral bleaching.

10.2. Coral transplantation frames (as on March 2017)

Many of the deployed coral transplantation frames were found damaged because of various factors. Among the total of 100 frames, 61 were found damaged and were not suitable for coral transplantation. Damaged frames were found toppled and were found in unsuitable positions. Many frames were totally broken as the iron rods used for the concrete are exposed. Many frames were found broken at one side. Invariably, all the frames were overgrown by fleshy macro algae mainly by *Caulerpa* sp. Following are the possible reasons for this degradation of concrete frames,

- Concrete frames have been deployed one on another. After deployment, about 15 months no care could be taken particularly to arrange them in position, transplantation and also monitoring due to local agitation.
- Fishing and tourist diving have happened in this transplantation site and the transplanted coral area was disturbed, knowingly or unknowingly. Out of the 50 slabs with coral fragments, only 4 slabs with coral fragments could be located.
- Since, the deployed frames could not be arranged properly due to local agitation, the strong waves and currents during monsoon season had also its impact.
- As regular monitoring could not happen, algae have overgrown the frames about one foot

10.3. Arrangement of frames and removal of algae

During March 2017, after the initial assessment of the deployed frames, efforts were taken to arrange them in proper position. Applying scuba diving, the frames which fell in improper positions were straightened. However, many frames were not recoverable as they were damaged severely. Algal overgrowth was very severe and the algae were removed using metal scrappers. Totally 39 frames were found suitable and transplantation on these frames was done with *Turbinaria* spp.

10.4. Transplants from December 2015

Transplantation of *Turbinaria* spp. had been done on five concrete frames with 50 cement slabs during December 2015. These transplants were found with good health and were found attached to cement slabs until May 2016. Currently, only four transplanted cement slabs were found on two concrete frames and were found alive. Rest of the slabs with transplants was not there on or near the frames. This is because of the fishing and tourism activities in this site. It was found that the damage to the transplanted fragments has been done deliberately to disturb the progress of the project. The transplants were good in condition and found attached to the substrates until May 2016 as the survival rate was 100%.

10.5. Transplantation during March 2017

As the concrete frames were already deployed, cement slabs of 20 cm X 15 cm X 1.5 cm were transferred from the construction site to the transplantation site via road and via boat. Coral fragments were collected from the donor site near Sindhudurg Fort and were taken to the transplantation site immediately without much stress. Tying of coral fragments onto the cement slabs was done on the way and the tying was done firmly. After reaching the site, the slabs with coral fragments were taken underwater and were arranged on concrete frames. Transplantation was done on those 39 frames recovered from the previous deployment and ten slabs were placed on each of the concrete frame. All the ten slabs were tied strongly to the frames to withstand the strong waves and currents.

10.6. Selection of new sites (March 2017)

Because of the agitations caused by the local fishermen, further deployment was not possible despite several awareness meetings. After discussions with fishermen, district administration and Forest department, the UNDP - GEF Sindhudurg project office decided to change site to Chivla beach in Malvan taluka and to Shiroda in Vengurla taluka. Site selection has been in Chivla beach and in Shiroda during March 2017. Site selection has been done along with the fishermen and tourist operators to avoid further delay. Necessary permission has been availed to do the activities in the new sites (Annexure 2)

Since donor sites were not found nearby, only artificial reef site was selected in Shiroda, Vengurla which is called Morya Chadhonta rock. It is planned to deploy only 25 Artificial Reef Modules as this site is far from the construction site and the road connecting these two places is very bad in condition.

Coral transplantation and artificial reef sites have been selected in Malvan, near a rock called Kavada rock which is near Chivla beach.

Rest of the coral transplantation frames are about to be deployed near Kavada rock in Chivla beach. Rock garden near Chivla beach has been selected as the donor site as it has a reasonable amount of corals to act as a donor site. Part of the artificial reef modules are about to be deployed in Kavada rock in Chivla (Malvan). According to the selection of new sites, none of the sites fall within the Malvan Marine Sanctuary. Following figues (Figs.2 and 3) and table (Table 1) provide the details of the newly selected sites.

Table 1: Newly selected sites in Malvan and Vengurla

Taluka	Site name	GPS	Depth	Location	Visibility
Vengurla	**Artificial reef site (Morya Chadhonta Rock)**	15^0 54.605” N 073^0 34.758” E	4-6m	200 m from the shore	2m
Malvan	**Donor site (Rock Garden)**	16^0 03.880” N 073^0 27.427” E	2 - 4m	200 m from the shore	3m
	Transplantation site (Kavada Rock)	16^0 06.051” N 073^0 26. 671” E	4 - 5m	30 m from Kavada rock shore	2m
	Artificial reef site (Kavada rock)	16^0 06. 063” N 073^0 26.721” E	6- 8m	150 m from Kavada rock shore	2m

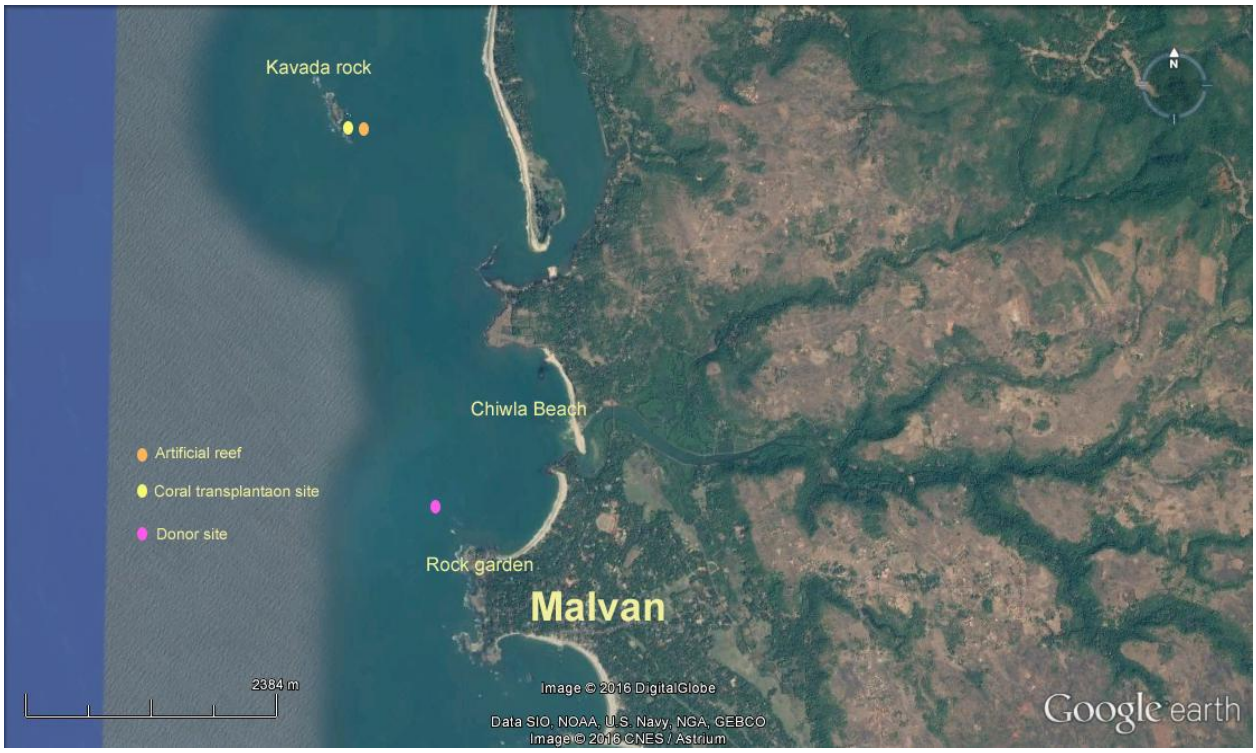

Fig. 2: Newly selected study sites in Malvan

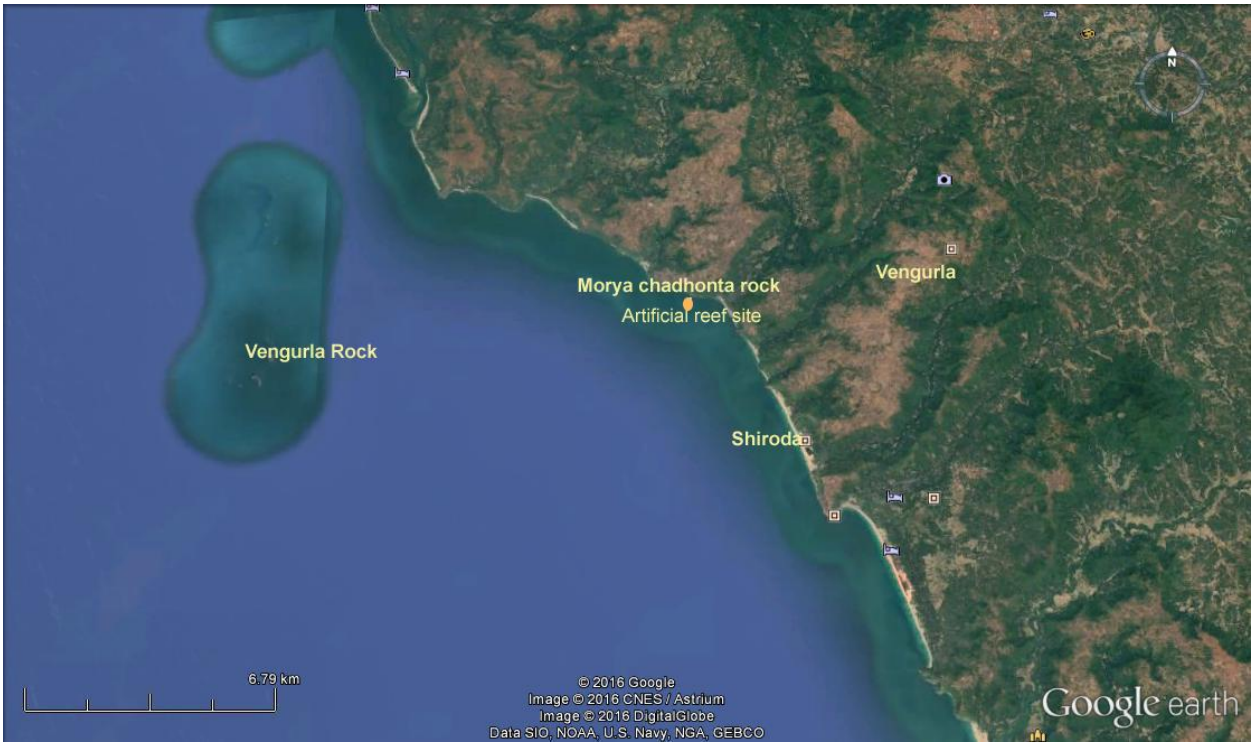

Fig. 3: Newly selected AR site in Vengurla

10.7. Baseline data collection in the new sites

Baseline data from all these sites was collected using standard protocols. Scuba diving was involved in site selection and random dives were made to ascertain the sites. Sandy area was selected for the deployment of artificial reefs to increase the fishery and other marine biodiversity. Selected transplantation site was rocky and sandy in nature to reduce the effect of sedimentation. Nearest coral reef area was selected as donor site to reduce the stress to the coral transplants. None of the currently selected sites falls within the boundary of Malvan Marine Sanctuary.

Assessment protocol involved scuba diving and the initial observation was done by visual assessment. Benthic community structure was assessed with 20 m Line intercept Transects (LIT) (English et al. 1997). Three transects were laid in each reef site and the direction of transects was parallel to the shore. Fish density in each site was assessed applying underwater visual census using belt transects (English *et al.*, 1997). Physico-chemical parameters such as temperature, salinity, pH, Total Suspened Solids (TSS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), calcium, magnesium, nitrate, nitrite and chloride levels were calculated using standard protocols.

Morya Chadhonta Rock - AR site at Shiroda (Vengurla)

This new artificial reef site occurs in Vengurla taluka near Shiroda village. This site is sandy and rocky in nature. Depth ranged between 4 and 6 m and it occurs about 200 m from the shore.

Benthic community structure is dominated by sand with 60.77% followed by rock and algae with 29.14 and 10.09%. Corals and other important benthic forms were not observed in this site. Totally six fish species were observed in this site and among them *Mahidolia mystacina* followed by *Epinephelus* sp. were the dominant fish species with 8.3 and 6 no.50m^{-2} respectively. Details are given in the figures 5 and 6.

At artificial reef site in Shiroda, all the physical and chemical parameters were found within the optimum limits (table 2); water temperature was 29.8°C; salinity was 37 ppt; EC was 31.9 mS/cm; turbidity was 5.6 NTU; pH was 8.2; TSS was 86 mg/l; DO was 4.9 mg/l; COD was 1.36 mg/l; BOD was 1.6 mg/l; calcium level was 500 mg/l; magnesium level was 1310 mg/l;

nitrate level was 1.22 µg/l; nitrite level was 1.11 µg/l; chloride level was around 17.7 g/l; oil and grease level was 0.2 mg/l.

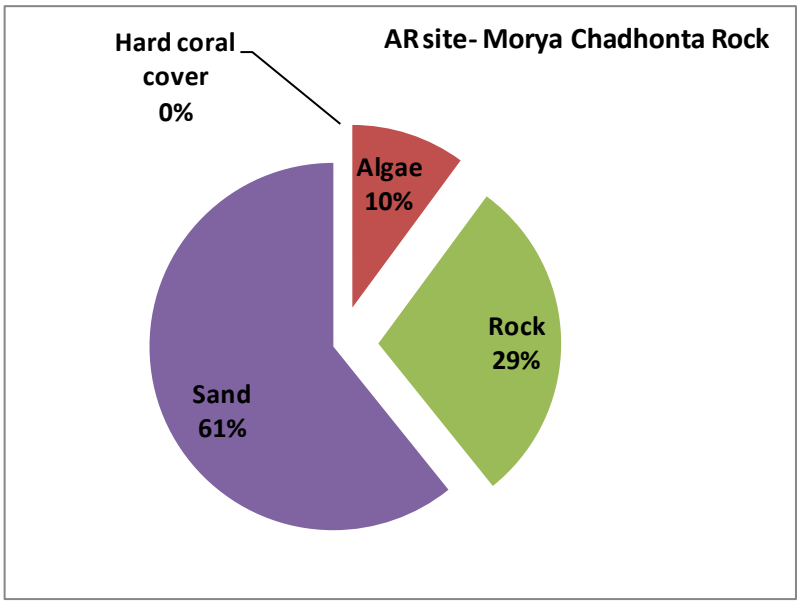

Fig. 5. Benthic community structure in Morya Chadhonta Rock

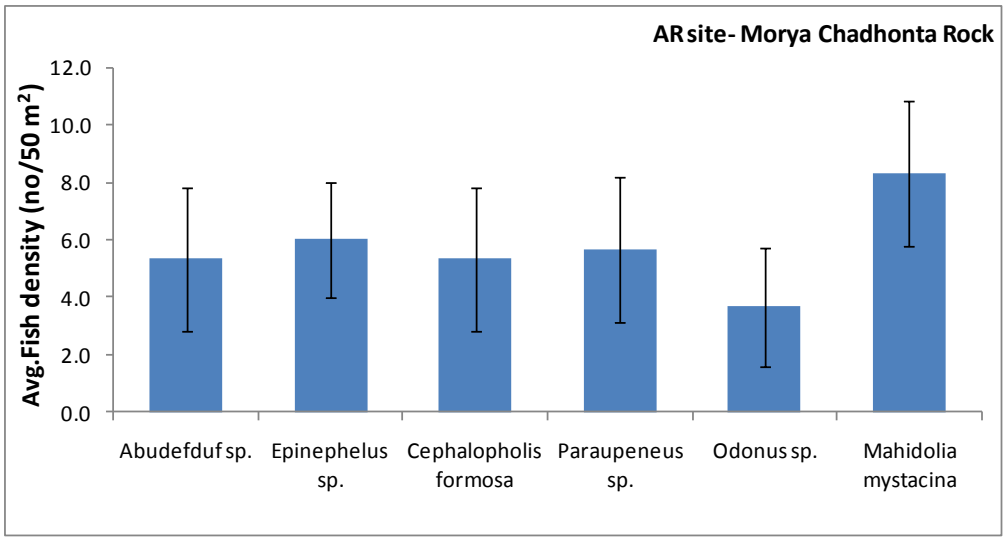

Fig.6. Fish abundance in Morya Chadhonta Rock

Rock Garden - Donor site (Malvan)

The new donor site is a typical reef area with the benthic community structure is dominated by hard corals. Depth ranged between 2 and 4 m and this site occurs 200 m away from the Chivla beach shore.

Donor site is dominated by live corals with 45.14% and algae covered 20.07%; rock and sand were 2.68 and 32.11% respectively. Totally 15 species of corals from 9 genera were observed in this site. *Turbinaria* was the dominant coral genus found in this site with 20.7% followed by *Goniastrea* with 2.7%. Percentage cover of other genera was as follows; *Favites* 3.3%; *Goniopora* 3.7%; *Favia* 1%; *Coscinaraea* 2.7%; *Pavona* 0.3%; *Porites* 2.3%; *Platygyra* 0.7%. Totally 20 fish species were recorded in this site and among them *Selaroides* sp. was the dominant species with 49.33 no.50m^{-2} followed by *Pempheris* sp. with 37.33 no.50m^{-2}. Details are given in the figures 7 to 9.

At donor site, all the physical and chemical parameters were within the optimum limits (table 2); water temperature was 29.6°C; salinity was 36 ppt; EC was 31.5 mS/cm; turbidity was 5.6 NTU; pH was 8; TSS was 82 mg/l; DO was 5 mg/l; COD was 1.46 mg/l; BOD was 1.8 mg/l; calcium level was 440 mg/l; magnesium level was 1217 mg/l; nitrate level was 1.3 µg/l; nitrite level was 0.4 µg/l; chloride level was around 17.1 g/l; oil and grease level was 0.15 mg/l.

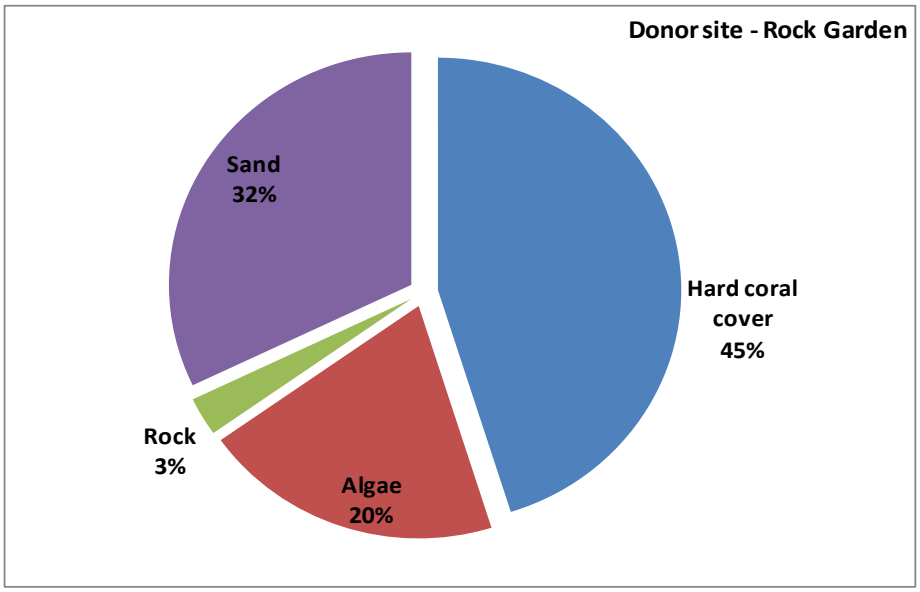

Fig. 7. Benthic community structure in Rock Garden

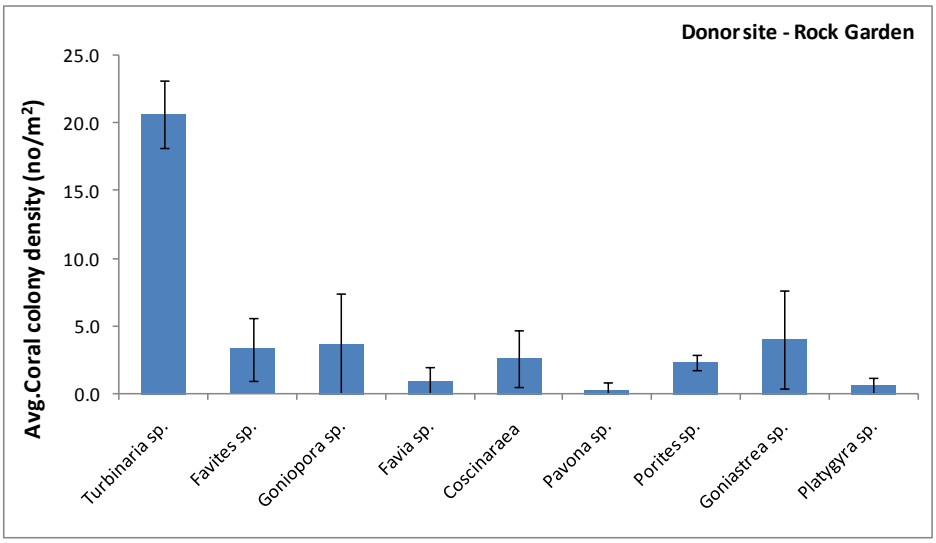

Fig. 8. Coral generic density in Rock Garden

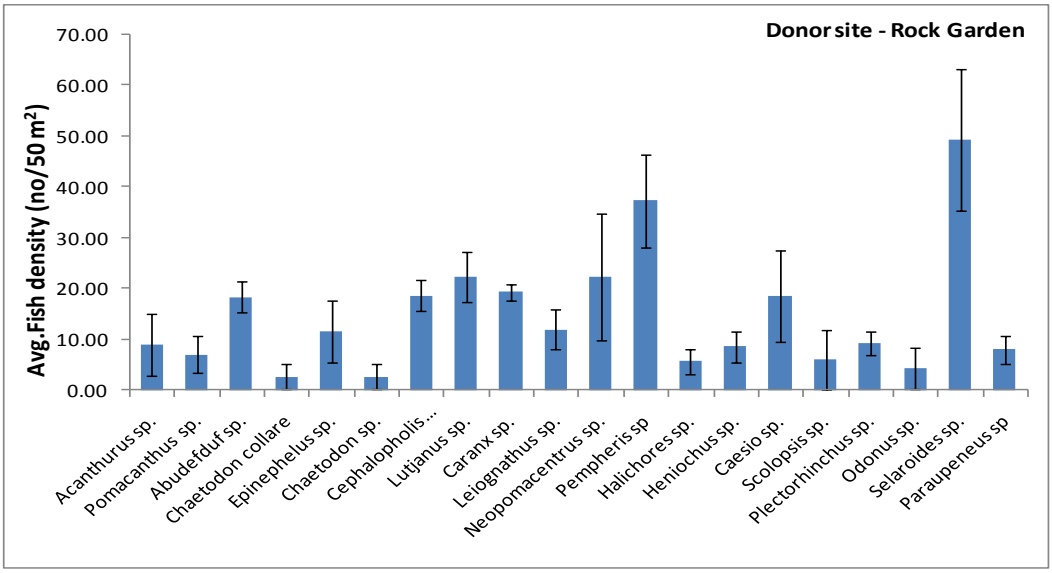

Fig.9. Fish abundance in Rock Garden

Observed coral species list in Rock Garden

14. *Pavona varians*
15. *Porites sp.*
16. *Coscinaraea monile*
17. *Platygyra* sp.
18. *P.lamellosa*

19. *Goniastrea retiformis*
20. *G.pectinata*
21. *Favites abdita*
22. *Favites flexuosa*
23. *Favia* sp.
24. *Favia pallida*
25. *Turbinaria mesenterina*
26. *T.peltata*
27. *Goniopora minor*
28. *Goniopora sp.*

Kavada Rock - Transplantation site at Chivla (Malvan)

This new transplantation site is a combination of sand and rock with very little amount of corals. Depth ranged between 4 and 5 m and this site occurs 30 m from the shore of Kavada rock.

Transplantation site in Chivla beach is dominated by sand and rock with 62.31 and 19.68% respectively. Live corals were also found in this site with 4.98% and octocorals were found with 3.41% while algae were found with 9.62%. Totally 6 species of corals from 4 genera were observed in this site and *Tubastrea* was the dominant genus with 4.7% followed by *Porites* with 1.3% while *Favites* and *Goniopora* were 1 and 0.7% respectively. Totally seven species of fishes were witnessed and among them *Leiognathus* sp. was the dominant with 15.7 no.50m^{-2} followed by *Pempheris* sp. with 9.33 no.50m^{-2}. Details are given in the figures 10 to 12.

At transplantation site in Chivla beach, all the physical and chemical parameters were within the optimum limits (table 2); water temperature was 29.6°C; salinity was 37 ppt; EC was 31.1 mS/cm; turbidity was 5.4 NTU; pH was 8.2; TSS was 80 mg/l; DO was 5.1 mg/l; COD was 1.17 mg/l; BOD was 1.7 mg/l; calcium level was 440 mg/l; magnesium level was 1231 mg/l; nitrate level was 1.2 µg/l; nitrite level was 0.23 µg/l; chloride level was around 17.4 g/l; oil and grease level was 0.11 mg/l.

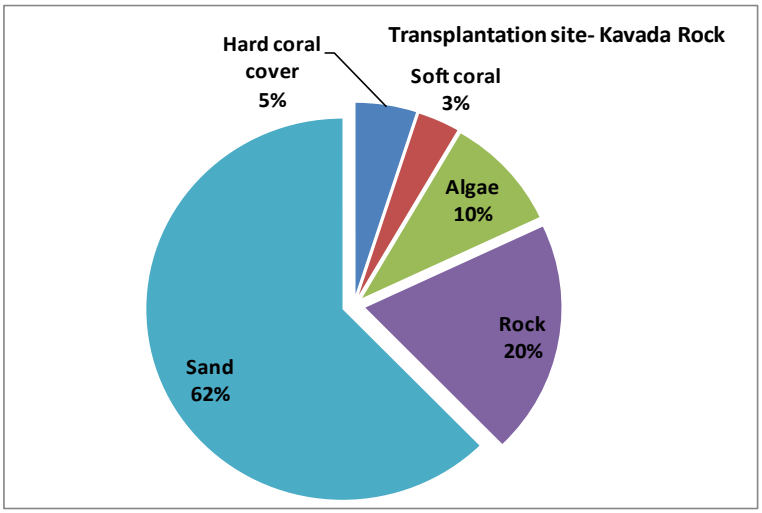

Fig. 10. Benthic community structure in Kavada Rock – Transplantation site

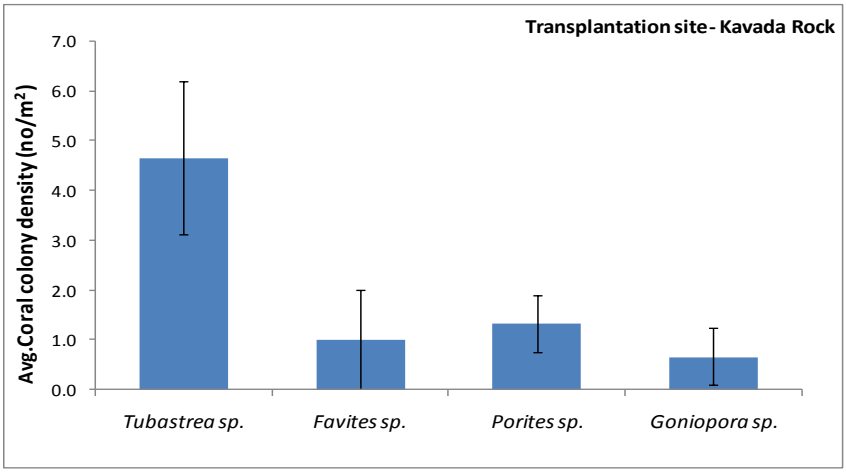

Fig. 11. Coral generic density in Kavada Rock – Transplantation site

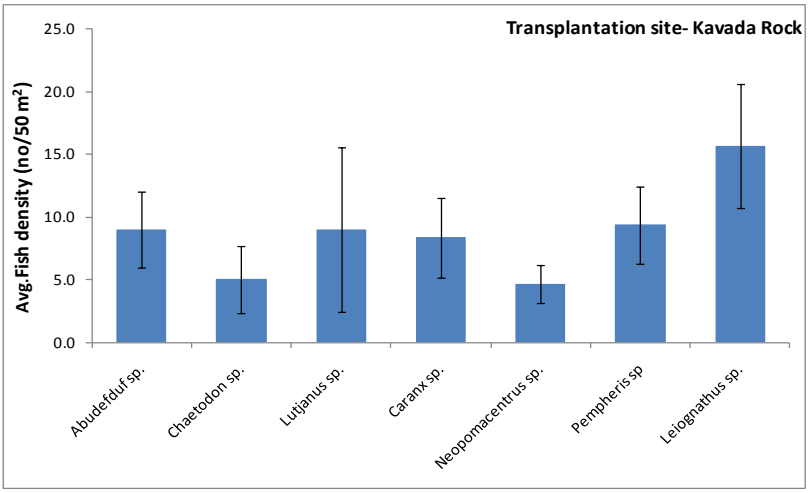

Fig.12. Fish abundance in Kavada Rock – Transplantation site

Observed coral species list in Kavada Rock – Transplantation site

1. *Tubastrea* sp.
2. *Favites flexuosa*
3. *Favites abdita*
4. *Goniopora minor*
5. *Porites lutea*
6. *Porites sp.*

Kavada Rock – AR site at Chivla (Malvan)

This new artificial reef site is sandy in nature and the depth ranged between 6 and 8m. This site occurs 150 m away from the Kavada rock.

Artificial reef site at Chivla beach is totally dominated by sand with 85.95% distantly followed by rock with 11.23% while algae were found with 2.82%. In this site totally four fish species were recorded and among them *Lutjanus* sp. was the dominant species with 8 no.50m^{-2} followed by *Selaroides* sp. with 6 no.50m^{-2}. Details are given in the figures 13 and 14.

At artificial reef site in Chivla, all the physical and chemical parameters were within the optimum limits (table2); water temperature was 29.7°C; salinity was 36 ppt; EC was 31.3 mS/cm; turbidity was 5 NTU; pH was 8.1; TSS was 79 mg/l; DO was 5 mg/l; COD was 1.25 mg/l; BOD was 1.7 mg/l; calcium level was 440 mg/l; magnesium level was 1244 mg/l; nitrate level was 1.29 µg/l; nitrite level was 0.2 µg/l; chloride level was around 17.4 g/l; oil and grease level was 0.13 mg/l.

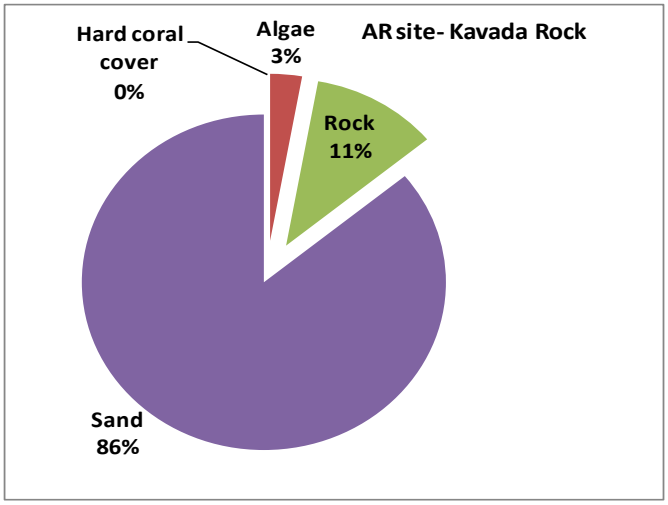

Fig. 13. Benthic community structure in Kavada Rock – AR site

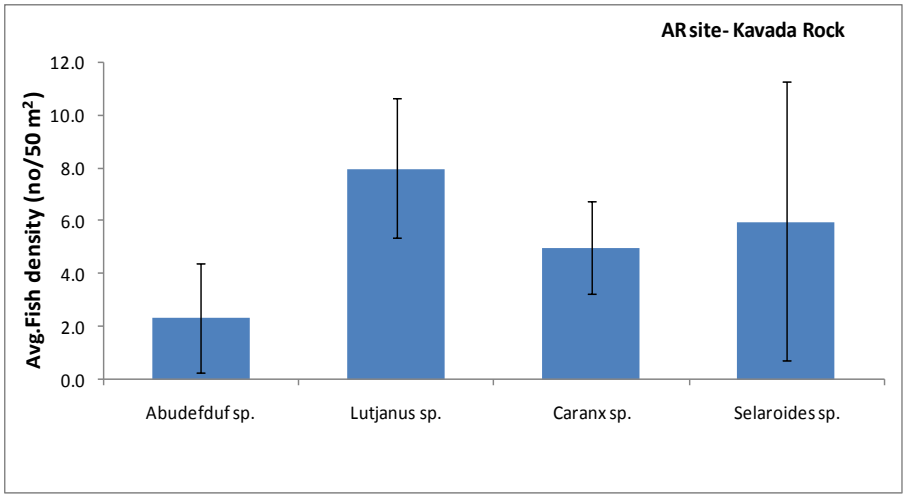

Fig.14. Fish abundance in Kavada Rock – AR site

Table 2: Physico- chemical parameters in the newly selected sites

	AR site Vengurla	**Donor site Malvan**	**Transplantation site Malvan**	**AR site Malvan**
Physical parameters				
Temperature (^{0}C)	29.8	29.6	29.6	29.7
Salinity (ppt)	37	36	37	36
EC (mS/cm)	31.9	31.5	31.1	31.3
Turbidity (NTU)	5.6	5.6	5.4	5
pH Value	8.2	8	8.2	8.1
TSS (mg/l)	86	82	80	79
Chemical parameters				
Do (Dissolved oxygen)	4.9	5	5.1	5
COD (mg/l)	1.36	1.46	1.17	1.25
BOD (mg/l)	1.6	1.8	1.7	1.7
Calcium (mg/l)	500	440	440	440
Magnesium (mg/l)	1310	1217	1231	1244
Nitrates (µg at/l)	1.22	1.3	1.2	1.29
Nitrites (µg at/l)	1.11	0.4	0.23	0.2
Chloride (g/l)	17.7	17.1	17.4	17.4
Oil & grease (mg/l)	0.0	0.15	0.11	0.13

10.8. Monitoring in the previously deployed artificial reef and coral transplantation

Artificial reef (Near Sindhudurg Fort)

Benthic community structure has been observed to be dominated by sand in this site with 84.2% during December 2015 and it was 82.5% during March 2017. Rock and algae were the other contributors. Colonization of fishes and other organisms have occurred in the artificial reef site. Only five fish species were recorded during December 2015 in the artificial reef site during the deployment and during March 2017, a total of 19 fish species were observed. Among the observed fish species, *Sphyraena* sp. followed by *Selaroides* sp. were the dominant species with 52 and 50.7 no. $50m^{-2}$ respectively. Details are given in the figures 15 to 18.

Molluscs, sponges, hydroids, ascidians, echinoderms and algae were the observed epiphytes on the artificial reef modules. Among them, ascidians were the dominant category with 2.4 $no.module^{-2}$ followed by algae with 2 $no.module^{-2}$. Molluscs, sponges, hydroids and echinoderms were found with 1.7, 1, 0.3 and 0.4 $no.module^{-2}$ respectively.

At artificial reef site near Sindhudurg Fort, all the physical and chemical parameters were within the optimum limits (table3); water temperature was 29.8°C; salinity was 36 ppt; EC was 31.8 mS/cm; turbidity was 5.5 NTU; pH was 8.1; TSS was 88 mg/l; DO was 5.1 mg/l; COD was 1.32 mg/l; BOD was 1.5 mg/l; calcium level was 460 mg/l; magnesium level was 1254 mg/l; nitrate level was 1.27 µg/l; nitrite level was 0.36 µg/l; chloride level was around 17.5 g/l; oil and grease level was 0.12 mg/l.

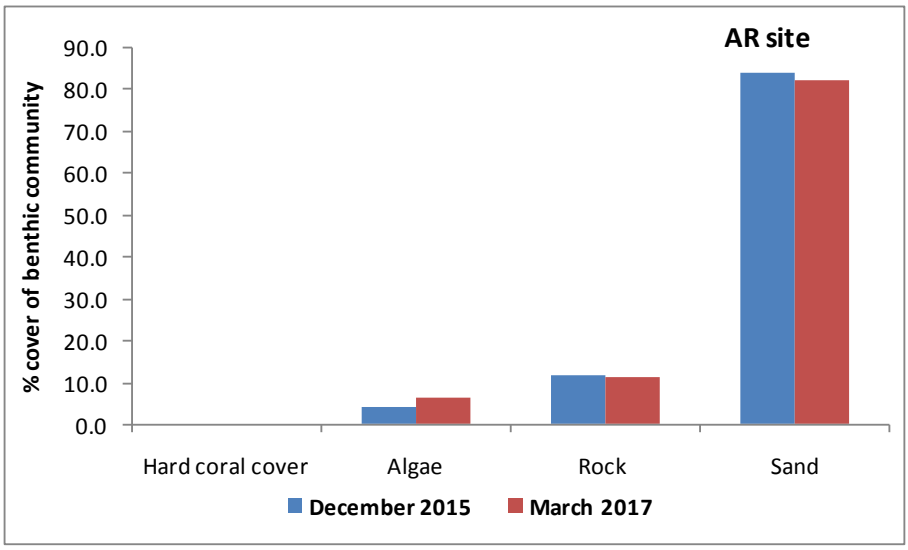

Fig. 15. Benthic community structure at AR site near Sindhudurg Fort during March 2017

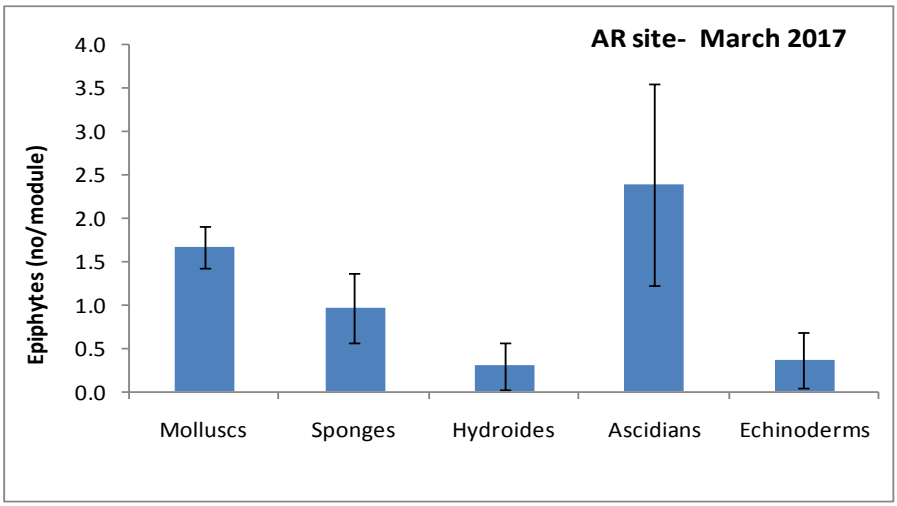

Fig. 16: Epiphyte density on AR modules near Sindhudurg Fort during March 2017

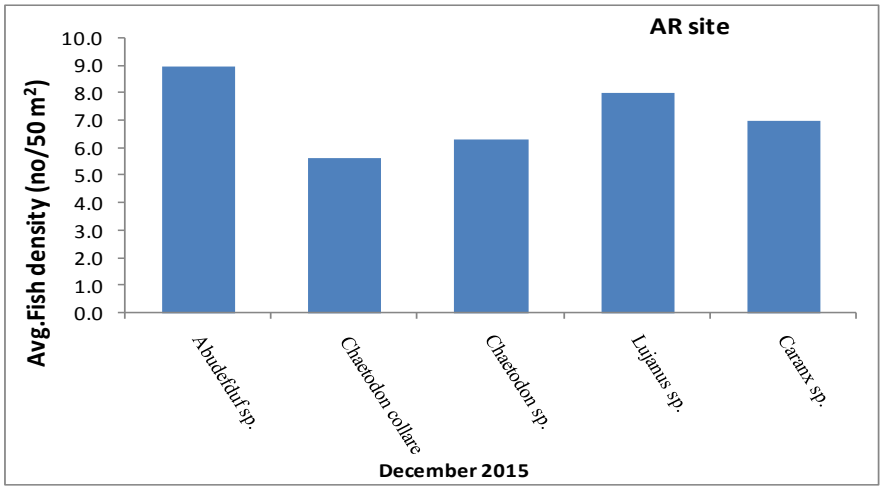

Fig. 17: Fish abundance in AR site near Sindhudurg Fort during December 2015

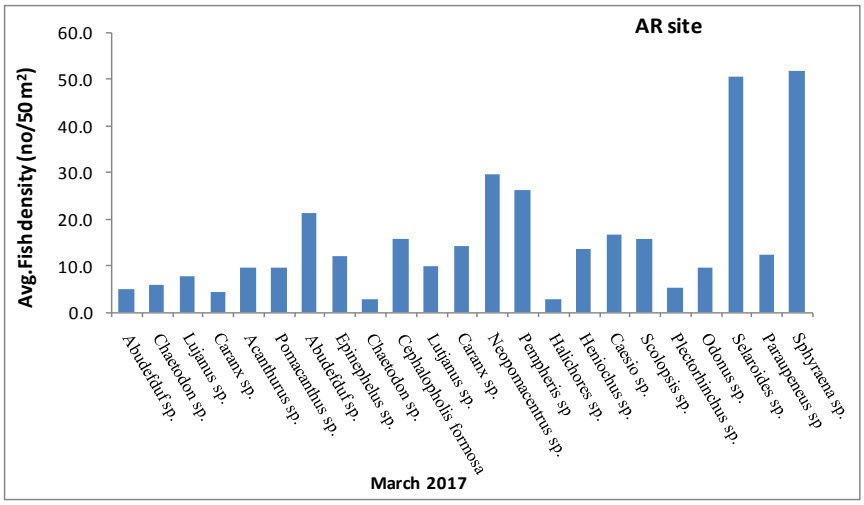

Fig. 18: Fish abundance in AR site near Sindhudurg Fort during March 2017

Transplantation site (Near Sindhudurg Fort)

Transplanted corals during December 2015 were monitored until May 2015 and were found in good health. Initial survival and attachment were also recorded before the monsoon season. However, only four transplants on two frames only were found and are in good shape and growing well.

In this transplantation site, live coral cover did not change significantly between December 2015 and March 2017 as it was 3.6 and 3.2% respectively. Sand and rock were the dominant benthic categories as they were 68.8 and 21.1% respectively while algae were 6.9% during March 2017. *Favites, Cyphastrea* and *Turbinaria* were the observed coral genera. Only four fish species were observed during December 2015 and seven species were observed during March 2017 and among them *Pempheris* sp. was dominant with 8.3 no.50m^{-2} followed by *Lutjanus* sp. with 6.7 no.50m^{-2}. Details are given in the figures 19 to 22.

All the physical and chemical parameters were within the optimum limits (table3); water temperature was 29.7°C; salinity was 37 ppt; EC was 31.4 mS/cm; turbidity was 5.8 NTU; pH was 8.2; TSS was 90 mg/l; DO was 4.9 mg/l; COD was 1.4 mg/l; BOD was 1.7 mg/l; calcium level was 480 mg/l; magnesium level was 1238 mg/l; nitrate level was 1.31 µg/l; nitrite level was 0.39 µg/l; chloride level was around 17.6 g/l; oil and grease level was 0.18 mg/l.

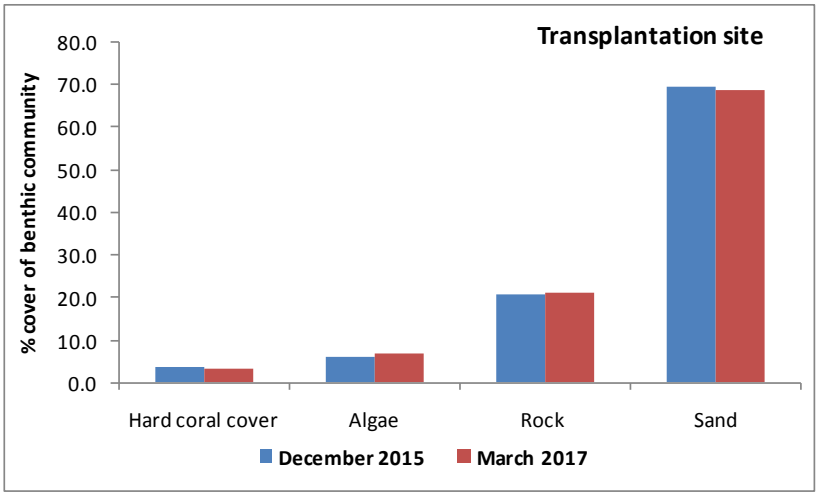

Fig. 19. Benthic community structure in transplantation site near Sindhudurg Fort during December 2015 and March 2017

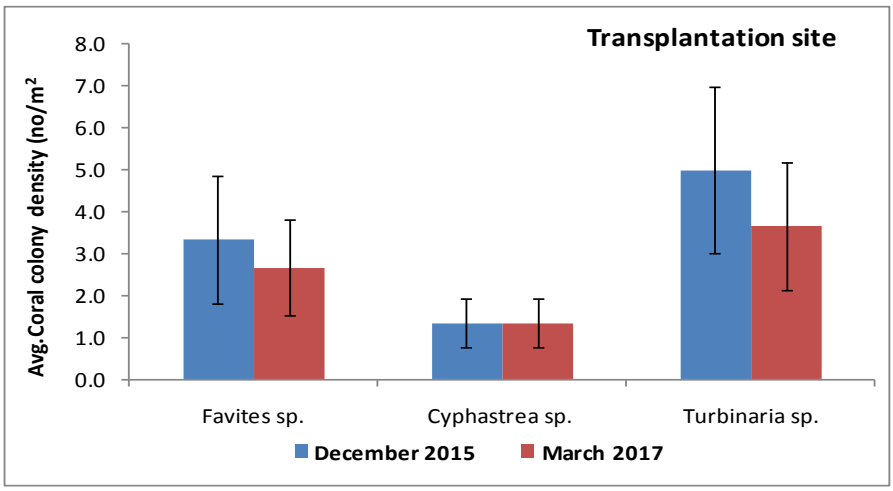

Fig. 20. Coral generic density in transplantation site near Sindhudurg Fort during December 2015 and March 2017

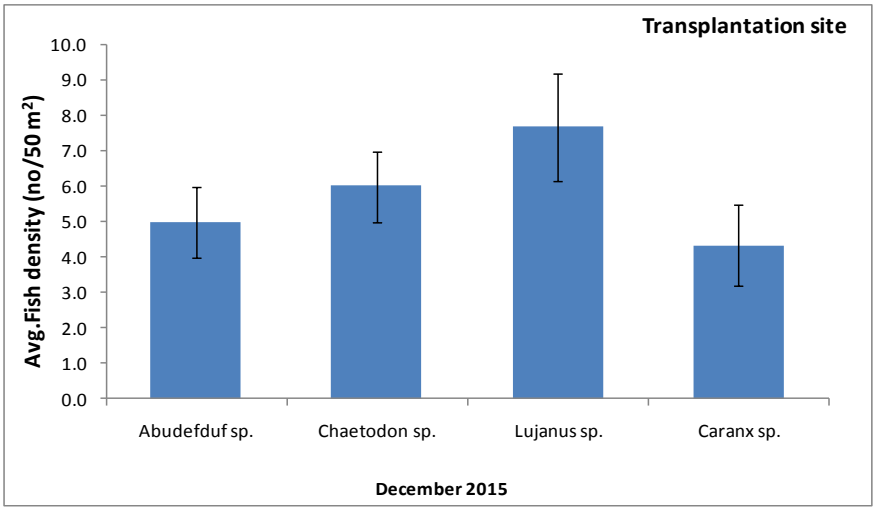

Fig. 21. Fish abundance in transplantation site near Sindhudurg Fort during December 2015

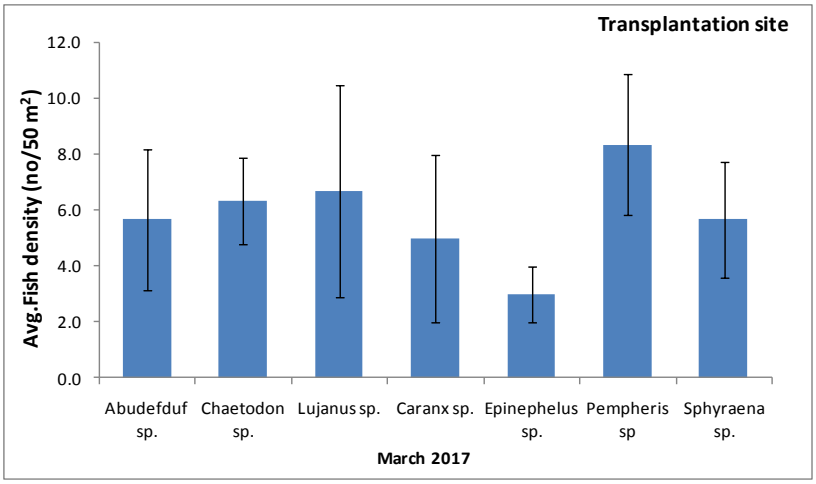

Fig. 22 Fish abundance structure in transplantation site near Sindhudurg Fort during March 2017

Table 3: Physio- chemical parameters in previously deployed artificial reef and coral transplantation sites

	AR site (Sindhudurg Fort)	Coral transplantation site (Sindhudurg Fort)
Physical parameters		
Temperature (^{0}C)	29.8	29.7
Salinity (ppt)	36	37
EC (mS/cm)	31.8	31.4
Turbidity (NTU)	5.5	5.8
pH Value	8.1	8.2
TSS (mg/l)	88	90
Chemical parameters		
Do (Dissolved oxygen)	5.1	4.9
COD (mg/l)	1.32	1.4
BOD (mg/l)	1.5	1.7
Calcium (mg/l)	460	480
Magnesium (mg/l)	1254	1238
Nitrates (µg at/l)	1.27	1.31
Nitrites (µg at/l)	0.36	0.39
Chloride (g/l)	17.5	17.6
Oil & grease (mg/l)	0.12	0.18

10.9. Summary (March 2017)

- A total of 100 concrete frames were deployed during December 2015 and a total of 250 artificial reef modules were also deployed.
- Because of the El nino triggered bleaching event during December 2015, transplantation was done only on five concrete frames which include 50 cement slabs. Prevalence of coral bleaching was 85.49% and only14.51% of corals was found healthy.
- *Turbinaria mesenterina* was the only transplanted species as it was found resistant to the bleaching event and was healthy.
- Corals recovered from bleaching during May 2016 as the prevalence of bleaching was only 7.0% and healthy corals were 82.8% and about 10.2% of coral mortality was recorded.
- Because of the hostility shown by the local fishermen from Malvan deployment was stopped and further deployment and transplantation could not be done until March 2017.
- Among the total of 100 frames, 61 were found damaged during March 2017 and were not suitable for coral transplantation.
- Many frames were found broken at one side and, all the frames were overgrown by fleshy macro algae mainly by *Caulerpa* sp.
- During March 2017, after the initial assessment of the deployed frames, efforts were taken to arrange them in proper position and the overgrown algae were removed using metal scrappers.
- Totally 39 frames were found suitable and transplantation on these frames was done with *Turbinaria* spp.
- Fishing and tourist diving have happened in this transplantation site and the transplanted coral area was disturbed, knowingly or unknowingly. Out of the 50 slabs with coral fragments, only 4 slabs with coral fragments could be located. Since, the deployed frames could not be arranged properly due to local agitation, the strong waves and currents during monsoon season had also its impact. As regular monitoring could not happen, algae have overgrown the frames about one foot
- The damage to the transplanted fragments could be done deliberately to disturb the progress of the project.

- After discussions with fishermen, district administration and Forest department, the UNDP-GEF Sindhugurg Project Office asked to change the sites to Chivla beach in Malvan taluka and to Shiroda in Vengurla taluka.
- Site selection has been in Chivla beach and in Shiroda during March 2017 along with the fishermen and tourist operators to avoid further delay.
- Since donor sites were not found nearby, only artificial reef site was selected in Shiroda, Vengurla which is called Morya Chadhonta rock.
- Coral transplantation and artificial reef sites have been selected near a rock called Kavada rock which is near Chivla beach in Malvan and rock garden near Chivla beach has been selected as the donor site.
- Baseline data has been collected from all new selected sites. Benthic community structure is dominated by sand with 60.77% followed by rock and algae with 29.14 and 10.09% at Morya Chadhonta rock in Vengurla.
- Donor site (Rock garden) is dominated by live corals with 45.14% and algae covered 20.07%; rock and sand were 2.68 and 32.11% respectively.
- Totally 15 species of corals from 9 genera were observed and *Turbinaria* was the dominant coral genus found in this site with 20.7% followed by *Goniastrea* with 2.7%.
- Transplantation site in Chivla beach (Kavada rlck) is dominated by sand and rock with 62.31 and 19.68% respectively while live corals were 4.98% and octocorals were 3.41%.
- Totally 6 species of corals from 4 genera were observed in this site and *Tubastrea* was the dominant genus with 4.7% followed by *Porites* with 1.3%.
- Artificial reef site at Chivla beach (Kavara rock) is totally dominated by sand with 85.95% distantly followed by rock with 11.23% and algae were found with 2.82%.
- Only five fish species were recorded during December 2015 in the artificial reef site (near Sindhudurg fort) and during March 2017, a total of 19 fish species were observed.
- Molluscs, sponges, hydroids, ascidians, echinoderms and algae were the observed epiphytes on the artificial reef modules.
- In transplantation site (near Sindhudurg fort), live coral cover did not change significantly between December 2015 and March 2017 as it was 3.6 and 3.2% respectively. *Favites, Cyphastrea* and *Turbinaria* were the observed coral genera and four coral species were recorded.

Photos

Broken concrete frames (used for transplantation) during March 2017

Transplantation concrete frames covered with algae during March 2017

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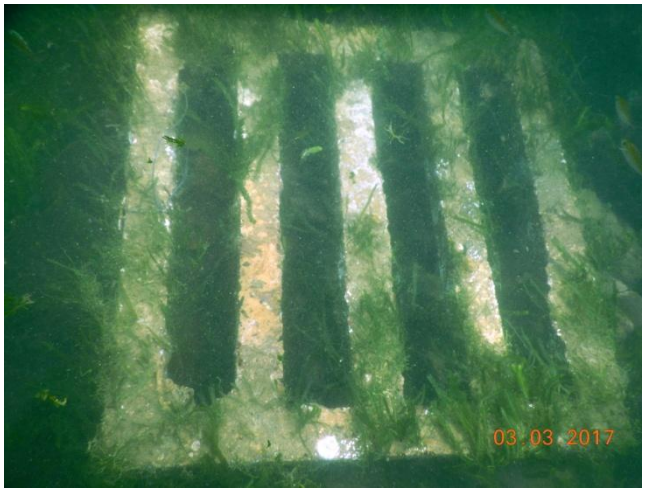
Removal of algae from concrete frames during March 2017

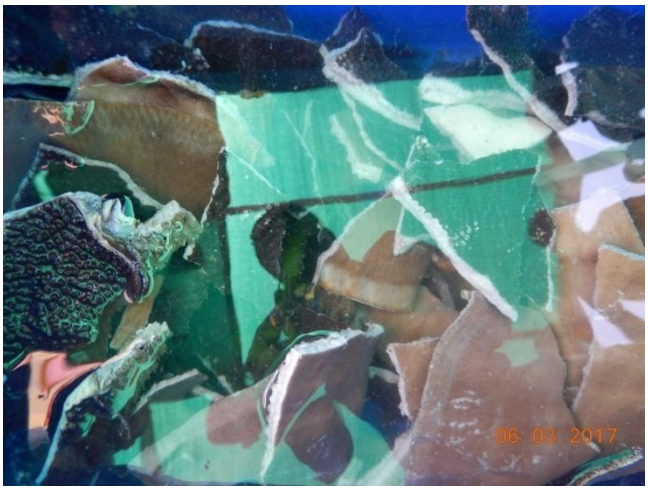
Arranged concrete frames after the removal of algae during March 2017



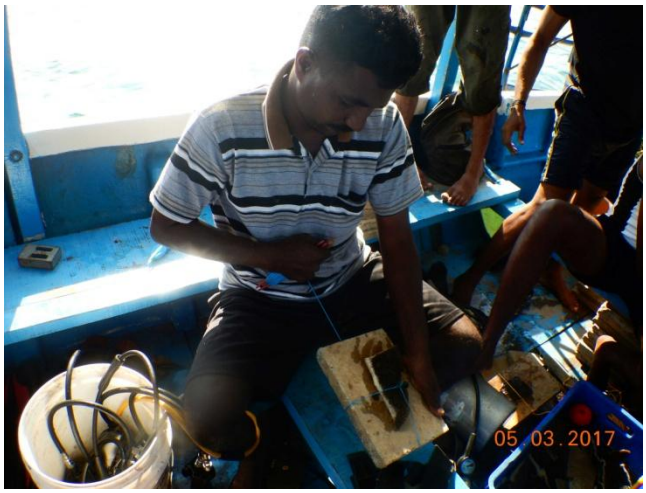
Surviving transplants from December 2015

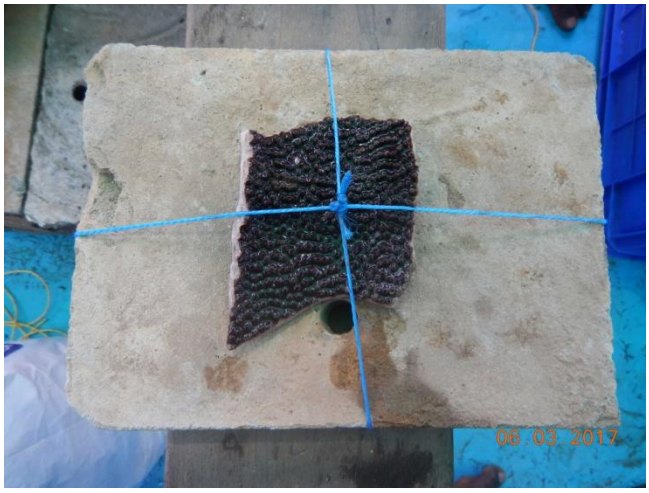
Transportation of cement slabs during March 2017

Collection of coral fragments from the donor site during March 2017



Tying of coral fragments on cement slabs during March 2017

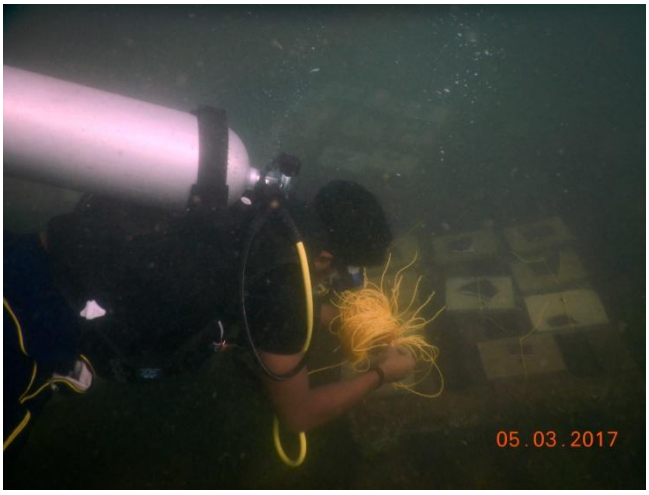


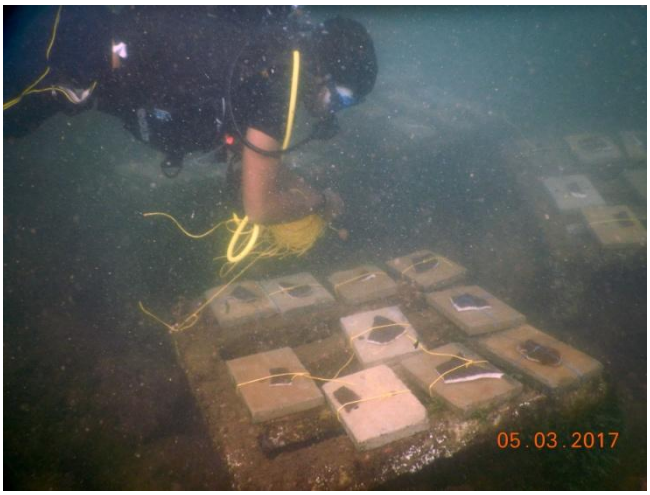


Transfer of slabs with tied fragments from the boat to the water during March 2017

Arrangement of slabs with coral fragments on concrete frames during March 2017

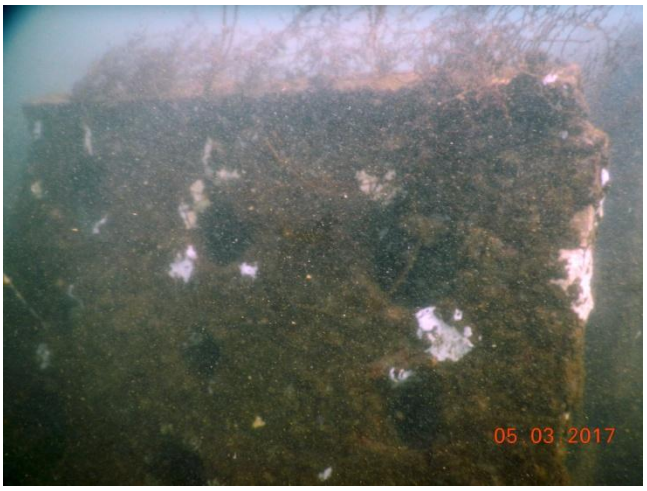
Tying the cement slabs with coral fragments on concrete frames during March 2017





Newly transplanted coral fragments during March 2017

Artificial reef modules deployed during December 2015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Fish assemblages on artificial reefs deployed during December 2015

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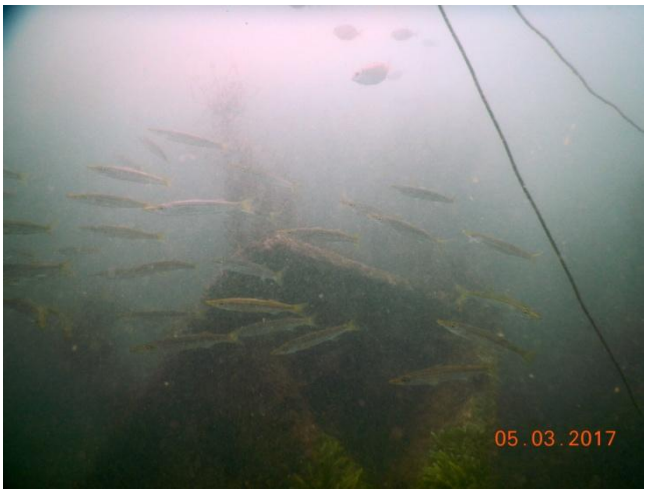
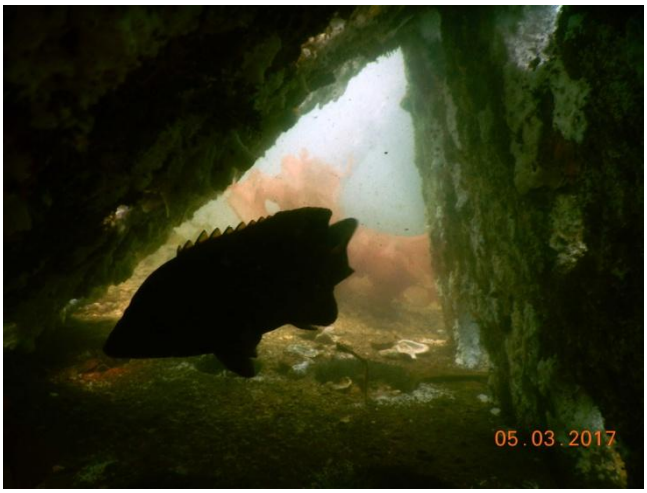
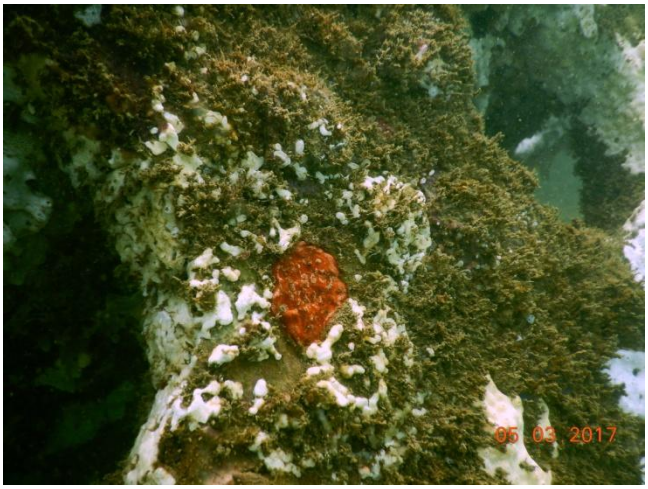
Fish assemblages on artificial reefs deployed during December 2015





Attachment of epiphytes on artificial reef modules deployed during December 2015



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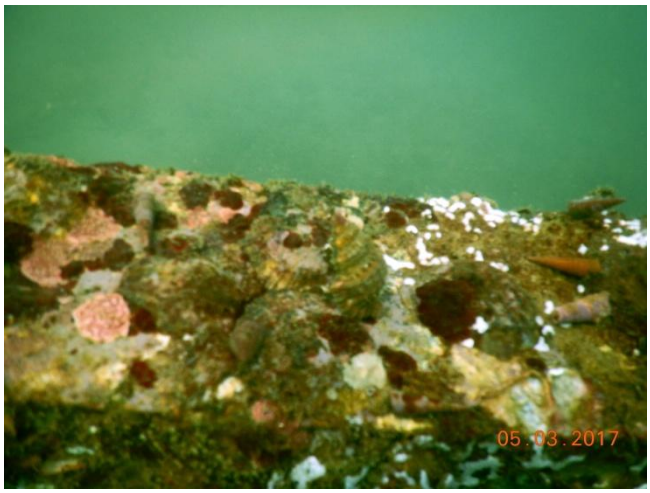

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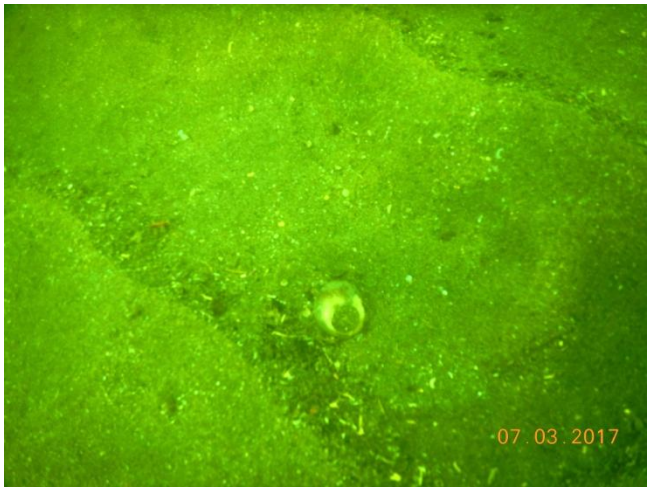
Site selection in Shiroda, Vengurla (Morya Chadhonta Rock)

AR site- Shiroda, Vengurla (Morya Chadhonta Rock)



AR site- Shiroda, Vengurla (Morya Chadhonta Rock)

Donor site – Chivla beach, Malvan (Rock Garden)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Donor site – Chivla beach, Malvan (Rock garden)


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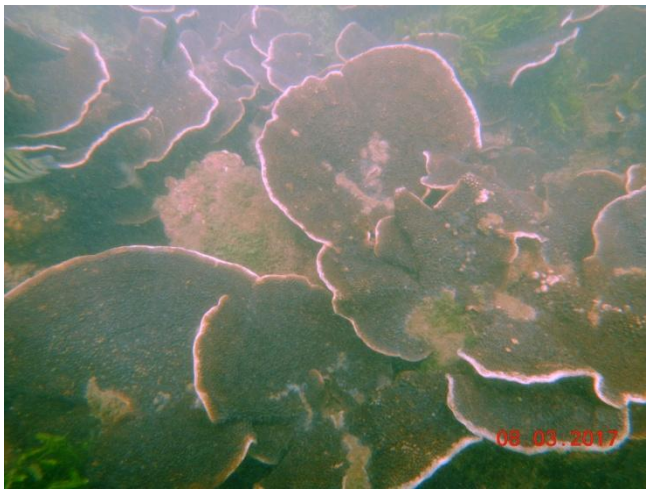
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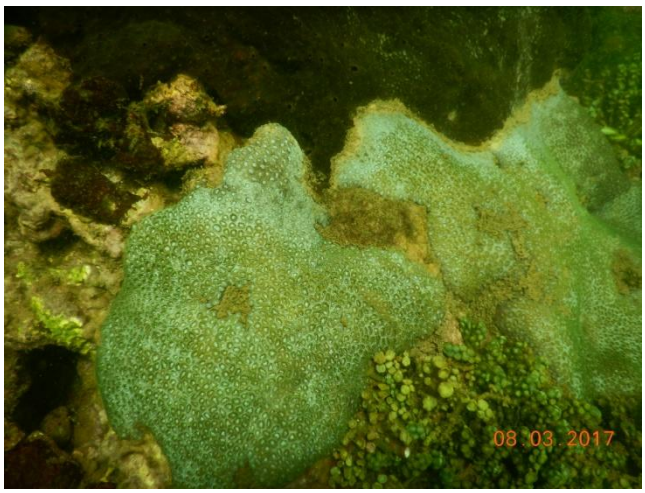
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Donor site – Chivla beach, Malvan (Rock garden)


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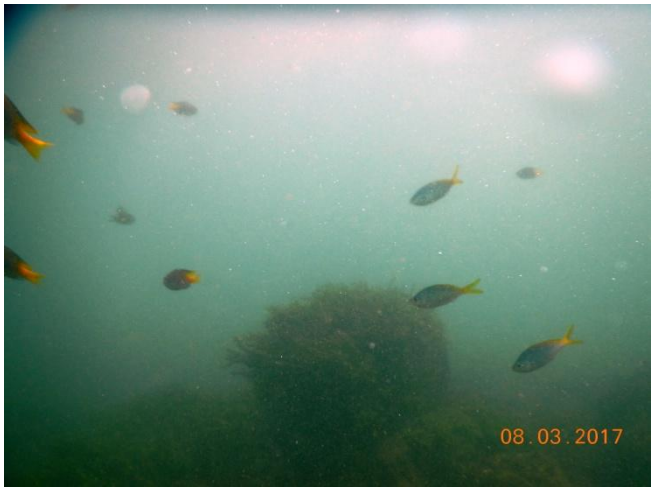
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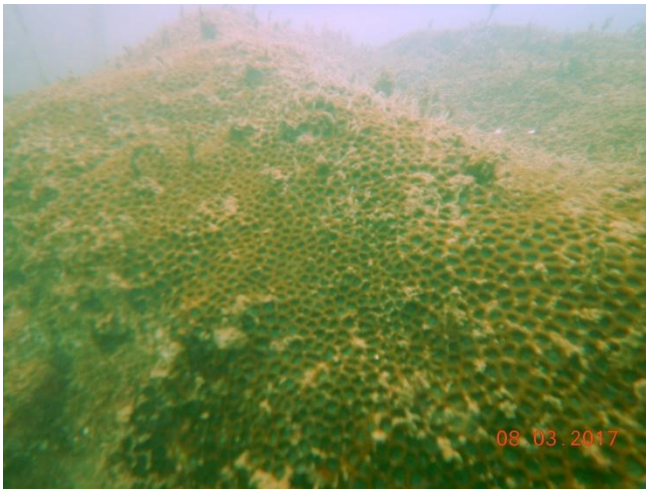
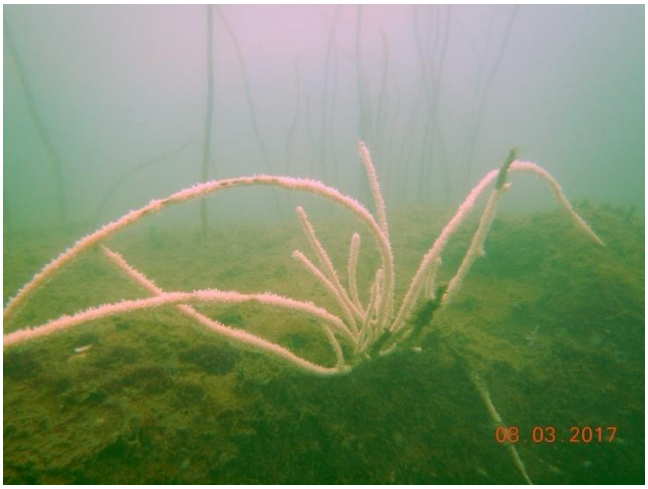
Donor site – Chivla beach, Malvan (Rock garden)

Site selection in Chivla Beach, Malvan (Kavada Rock)

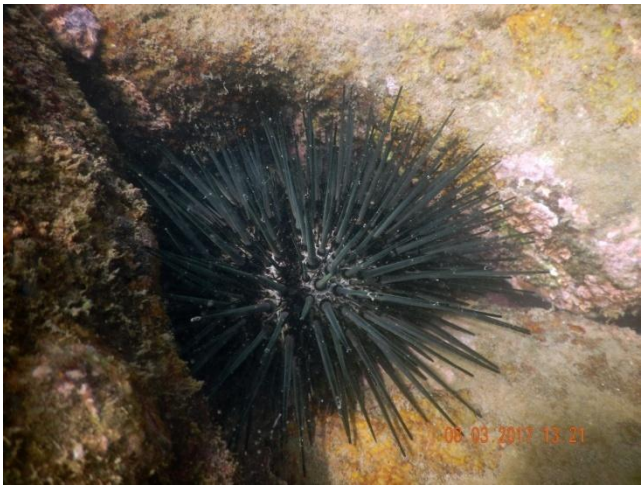
Transplantation site - Chivla Beach, Malvan (Kavada Rock)



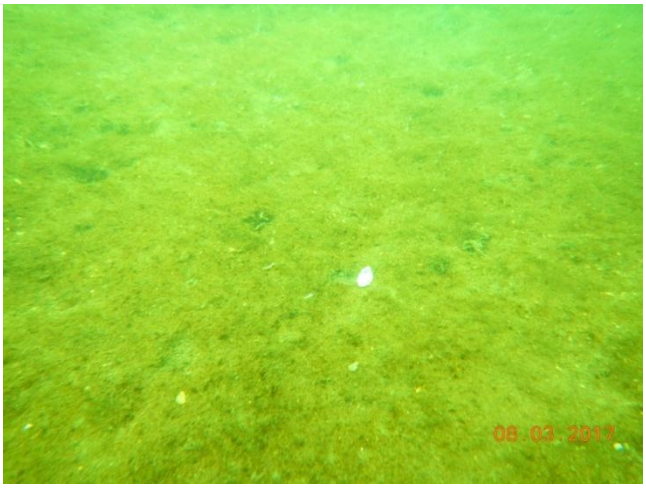
Transplantation site - Chivla Beach, Malvan (Kavada Rock)



Transplantation site - Chivla Beach, Malvan (Kavada Rock)



AR site - Chivla Beach, Malvan (Kavada Rock)



11. Deployment of Artificial Reefs and Coral Transplantation in new sites

Because of the El nino triggered bleaching event during December 2015, restoration was done only on five concrete frames which include 50 cement slabs. *Turbinaria mesenterina* was the only transplanted species as it was found resistant to the bleaching event and was healthy. Then, because of the hostility shown by the local fishermen from Malvan, deployment was stopped. These transplants were found with good health and were found attached to cement slabs until May 2016. During March 2017, only four transplanted cement slabs were found on two concrete frames and were found alive. Rest of the transplants was not there on or near the frames along with the cement slabs. This is because of the fishing and tourism activities along with the strong waves and currents in this site. During March 2017, transplantation was done on 39 frames which were recovered from the previous deployment and ten slabs were placed on each of the concrete frame.

Because of the agitations caused by the local fishermen, further deployment was not possible despite several awareness meetings. After discussions with fishermen, district administration, Forest department and the funding agency, sites were changed to Kavada rock at Chivla beach in Malvan taluka. Rock garden near Chivla beach was selected as the donor site as it has a reasonable amount of corals to act as a donor site.

Table 1. Newly selected sites near Chivla beach in Malvan

Taluka	Site name	GPS	Depth	Location	Visibility
Malvan	**Donor site (Rock Garden)**	16^0 03.880” N 073^0 27.427” E	2 - 4m	200 m from the shore	3m
	Transplantation site (Kavada Rock)	16^0 06.051” N 073^0 26. 671” E	4 - 5m	30 m from Kavada rock shore	2m
	Artificial reef site (Kavada rock)	16^0 06. 063” N 073^0 26.721” E	6- 8m	150 m from Kavada rock shore	2m

Fig. 2. Newly selected study sites near Chivla beach in Malvan

11.1. Deployment of Concrete frames and AR modules

Deployment was started in Chivla beach at Kavada rock on 24th April 2017. Deployment of artificial reef modules and concrete frames was completed on 3rd May 2017. Deployment was done with a mechanized trawler and the structures were taken underwater using floating barrels. All the structures were arranged in order under the water. A total of 201 concrete frames and 197 artificial reef modules were deployed in Kavada rock at respective sites. Following table provides the datewise details of deployment.

Table 2. Datewise detail of deployment

Date	Concrete Frames	AR Modules
24-04-2017	50	
25-04-2017	60	
26-04-2017	56	
27-04-2017	35	
28-04-2017		25
29-04-2017		50
30-04-2017		45

01-05-2017		25
02-05-2017		25
03-05-2017		27
Total	**201**	**197**

11.2. Transplantation

Coral transplantation on deployed concrete frames in Kavada rock was done during April-May 2017. Concrete slabs were transferred to the Chivla beach jetty and were transferred to the boat. The selected donor site was Rock garden where donor fragments were collected. Since *Turbinaria* spp. was found resistant to the coral bleaching, transplantation was done only with *Turbinaria* colonies. Donor colonies were fragmented under the water using hammer and chisel and were brought to the boat where they were kept in plastic tubs with water. Fragmentation was not more than 30% of the colony size not to damage the donor colonies. Collected fragments were further fragmented. Precision and care was taken during fragmentation and transportation of fragments to the transplantation site. Fragments were then tied with cement slabs tightly on the boat and were taken under water. Minimum ten slabs were arranged on each concrete frame and were tied strongly with the concrete frames. Because of the poor visibility and strong waves, transplantation was tedious and time consuming. Following table provides the datewise details of the transplantation.

Table 3. Datewise detail of transplantation

Date	No. of Frames transplanted
28-04-2017	46
29-04-2017	51
02-05-2017	64
03-05-2017	40
Total	**201**

11.3. Physico-chemical parameters

Water samples were collected from all the study sites which include donor site (Rock garden), transplantation site (Kavada rock) and artificial reef site (Kavada rock). Water samples were collected also from the previous transplantation and artificial reef sites (inside MMS).

Analysed physic-chemical parameters were more or less similar in all the sites because of the proximity. In Chivla beach, temperature ranged between 29.5 and 29.7º C; salinity was 35 ppt; pH ranged between 7.97 and 7.99; total suspended solids ranged between 169 and 175 mg/l; dissolved oxygen ranged between 4.6 and 4.8 mg/l; visibility ranged between 0.2 and 0.6m

In sites inside the MMS, temperature ranged between 29.5 and 29.6º C; salinity was between 35 and 36 ppt; pH ranged between 7.98 and 7.99; total suspended solids ranged between 169 and 174 mg/l; dissolved oxygen ranged between 4.5 and 4.9 mg/l; visibility ranged between 0.2 and 1.5m. Details of physic-chemical parameters at each site during April-May 2017 are given in the table.

Table 4. Physico-chemical parameters at each site during April-May 2017

	Kavada rock (AR)		**Kavada rock (TR)**		**Rock garden**		**MMS (TR)**		**MMS (AR)**	
Parameters	**Sur**	**Bot**	**Sur**	**Bot**	**Sur**	**Bot**	**Sur**	**Bot**	**Sur**	**Bot**
Temperature (°C)	29.7	29.6	29.7	29.5	29.6	29.6	29.6	29.5	29.6	29.5
Salinity (ppt)	35	35	35	35	35	35	36	35	35	36
pH	7.98	7.98	7.99	7.98	7.97	7.98	7.98	7.99	7.98	7.98
Total Suspended Solids (mg/l)	171	175	169	172	174	176	174	172	169	171
Dissolved Oxygen Content (mg/l)	4.7	4.6	4.8	4.8	4.8	4.7	4.9	4.5	4.7	4.6
Visibility (m)	0.4	0.3	0.4	0.2	0.6	0.6	1.5	1.5	0.5	0.2

11.4. Monitoring of AR and CT sites inside the MMS

Coral transplantation site inside MMS

Coral fragments were found alive with more than 95% survival rate and were found healthy and growing well. Among the 39 concrete frames transplanted during March 2017, about 50% of the slabs were found scattered near the frames in spite of being tied strongly. This is because of the strong waves and currents. Fallen slabs were placed again on the frames and were tied with the frames.

Artificial reef site inside MMS

Artificial reef modules inside the MMS were found attracting flora and fauna. Colonization by ascidians, gorgonians, gastropods, bivalves, hydroids, sponges, echinoderms, macro algae, etc. was recorded on the modules. Ascidians were the dominant category attached on the modules. Due to the poor visibility and lack of light, very few fishes could be spotted which include *Epinephelus* sp., *Pempheris* sp., *Sphyraena* sp., *Lutjanus* sp., *Cephalopolis formosa,* etc.

Table 5. Coral transplantation and monitoring during April-May 2017 field participants

Date	Participants	Organization	Deployment	Transplantation in Kavada rock	Monitoring in MMS
24-04-2017	Vishal Bhave, Milind	BNHS			
25-04-2017	Vishal Bhave, Milind	BNHS			
26-04-2017	Vishal Bhave, Milind	BNHS			
27-04-2017	Vishal Bhave, Milind	BNHS			
28-04-2017	K. Diraviya Raj, G. Mathews, R. L. Laju, M. Selva Bharath, A. Arasamuthu, A. Sahaya Mani, N. Stephen, S. Mohammad Samsudeen, B. Sahul Hameed Vishal Bhave, Milind Rohit Sawant	SDMRI BNHS UNDP			
28-04-2017	Vishal Bhave, Milind	BNHS			
29-04-2017	K. Diraviya Raj, G. Mathews, R. L. Laju, M. Selva Bharath, A. Arasamuthu, A. Sahaya Mani, N. Stephen, S. Mohammad Samsudeen, B. Sahul Hameed Durga Thigale	SDMRI UNDP			

29-04-2017	Vishal Bhave, Milind	BNHS			
30-04-2017	Vishal Bhave, Milind	BNHS			
01-05-2017	Vishal Bhave, Milind	BNHS			
02-05-2017	K. Diraviya Raj, R. L. Laju, M. Selva Bharath, A. Arasamuthu, A. Sahaya Mani, N. Stephen, S. Mohammad Samsudeen, B. Sahul Hameed	SDMRI			
02-05-2017	Vishal Bhave, Milind	BNHS			
03-05-2017	G. Mathews, R. L. Laju, M. Selva Bharath, A. Arasamuthu, A. Sahaya Mani, N. Stephen, S. Mohammad Samsudeen, B. Sahul Hameed Vishal Bhave Rohit Sawant	SDMRI BNHS UNDP			
03-05-2017	Vishal Bhave, Milind	BNHS			
03-05-2017	K. Diraviya Raj Vishal Bhave Rohit Sawant	SDMRI BNHS UNDP			

Summary (November 2017)

- Deployment of artificial reef modules and concrete frames was started in Chivla beach at Kavada rock on 24th April 2017 and was completed on 3rd May 2017.
- Deployment was done with a mechanized trawler and the structures were taken underwater using floating barrels and all the structures were arranged in order under the water.
- A total of 201 concrete frames and 197 artificial reef modules were deployed in Kavada rock at respective sites.
- Coral transplantation on deployed concrete frames in Kavada rock was done during April-May 2017.
- Transplantation was done only with *Turbinaria* colonies.
- Because of the poor visibility and strong waves, transplantation was tedious and time consuming.
- Physico-chemical parameters of the study sites were within the optimum levels except visibility which was very poor.
- Coral fragments were found alive with more than 95% survival rate and were found healthy and growing well at transplantation site in the MMS.
- Among the 39 concrete frames transplanted during March 2017, about 50% of the slabs were found scattered near the frames because of the strong waves and currents.
- Fallen slabs were placed again on the frames and were tied with the frames.
- Artificial reef modules inside the MMS were found attracting flora and fauna. Colonization by ascidians, gorgonians, gastropods, bivalves, hydroids, sponges, echinoderms, macro algae, etc. was recorded on the modules.
- A training handbook has been prepared for training the locals and Forest Department people in coral transplantation in English and Marathi (Prepared Draft Rehabilitation Manual in English and Marathi which are attached as Annexure 3 and 4 respectively)

Concrete frames deployment at Kavada rock

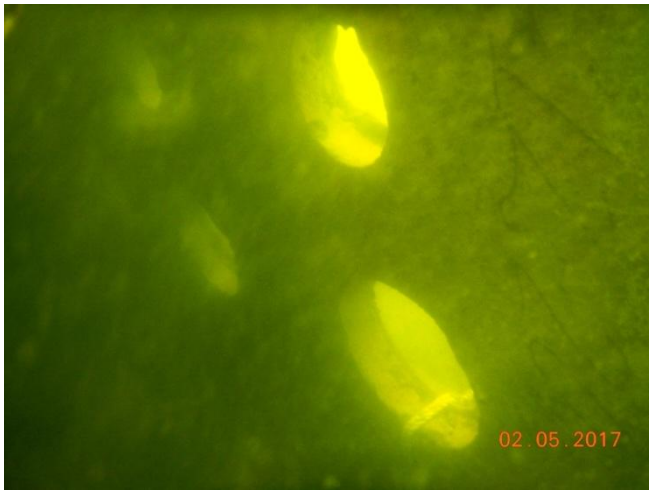
AR deployment at Kavada rock

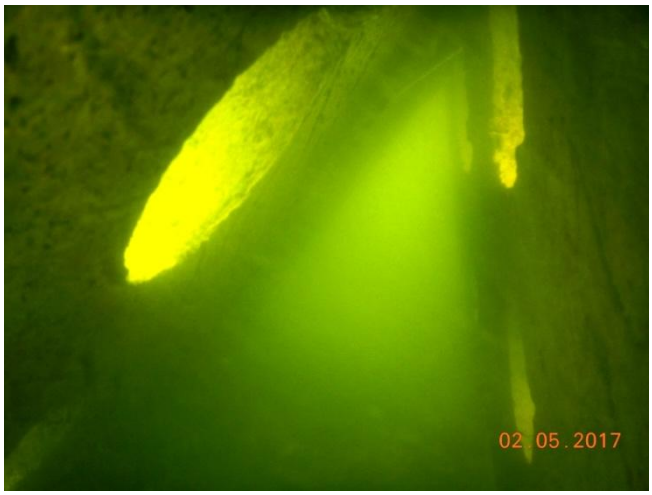
Deployed concrete frames at Kavada rock

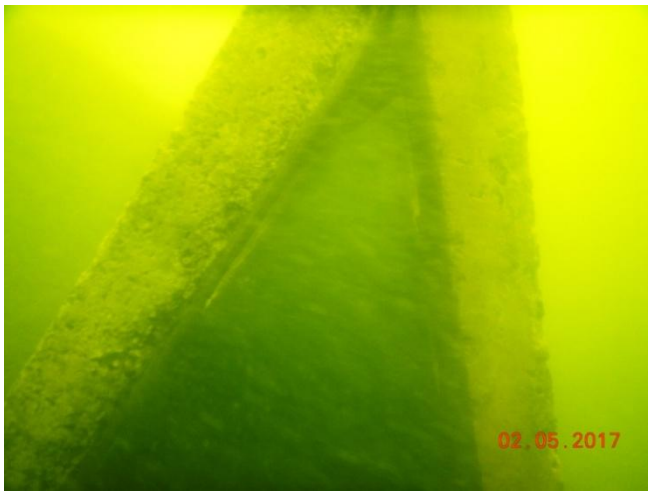





Deployed AR at Kavada rock

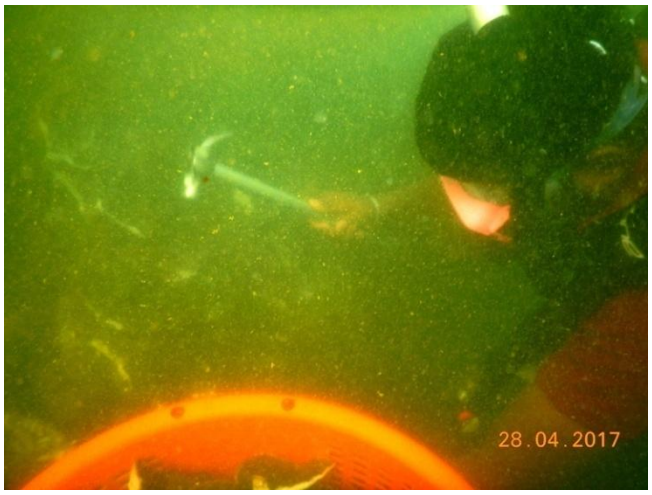






Transportation of cement slabs to boat in Chivla beach

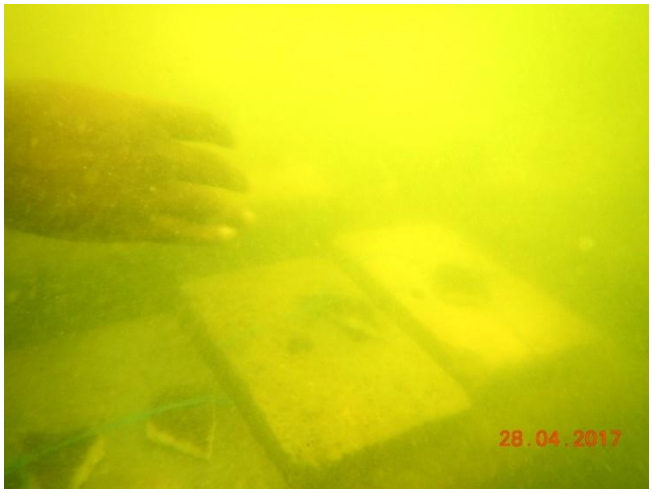
Donor fragment collection from Rock garden



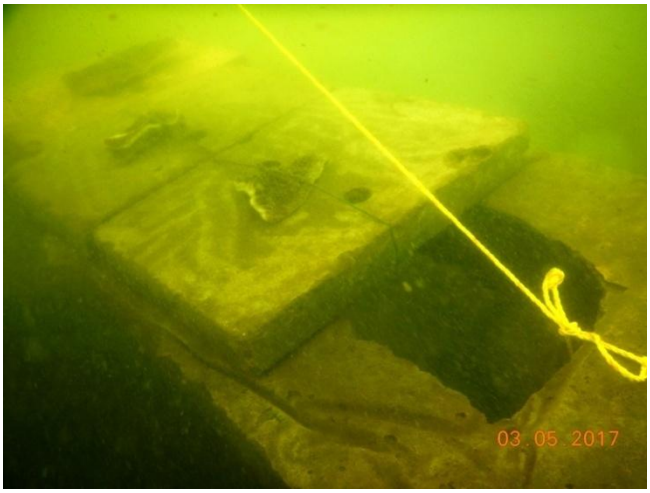
Tying of coral fragments onto cement slabs at Kavada rock

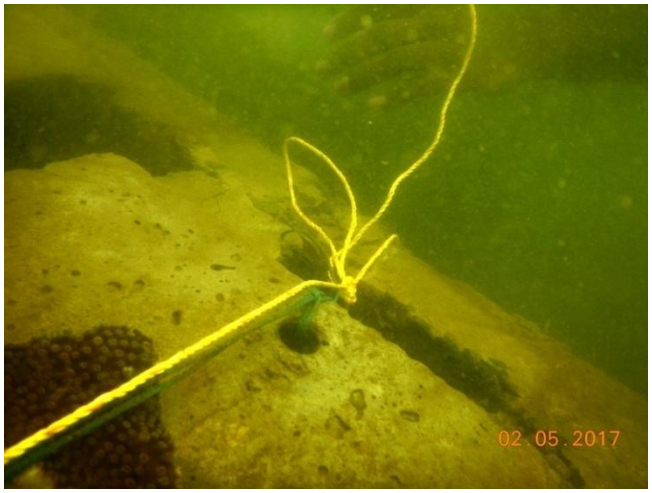
Transportation of tied fragments to deployed frames at Kavada rock

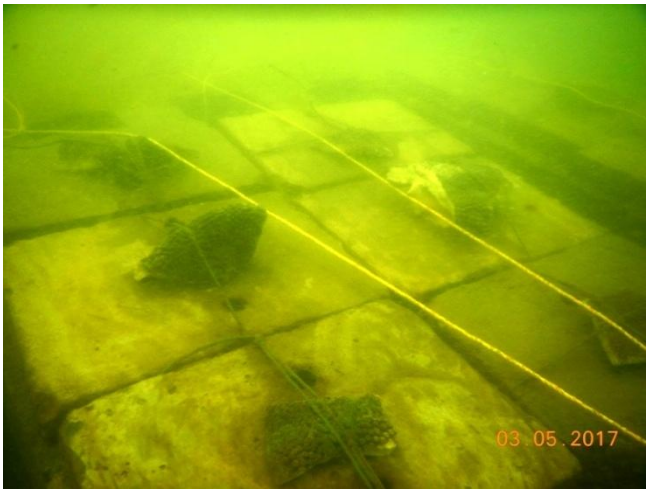
Placement of cement slabs on concrete frames at Kavada rock



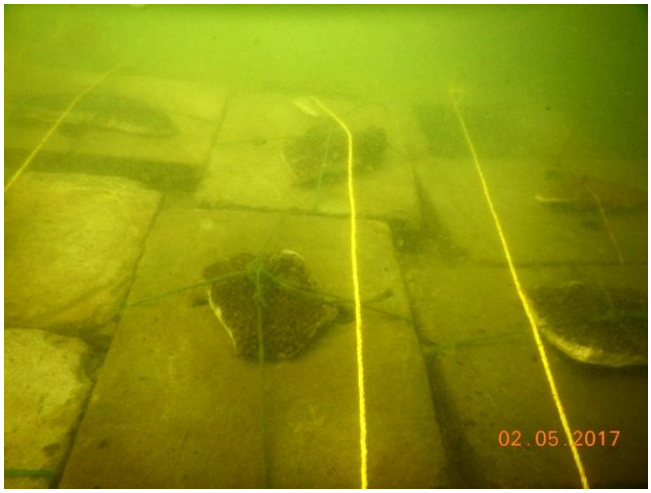
Tying of slabs with concrete frames at Kavada rock

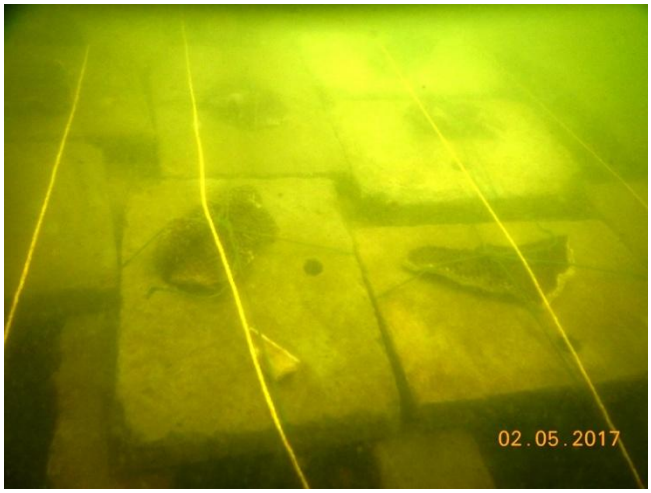


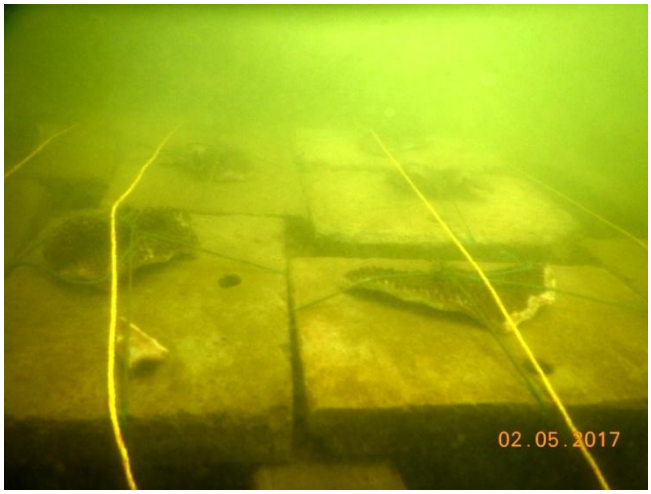


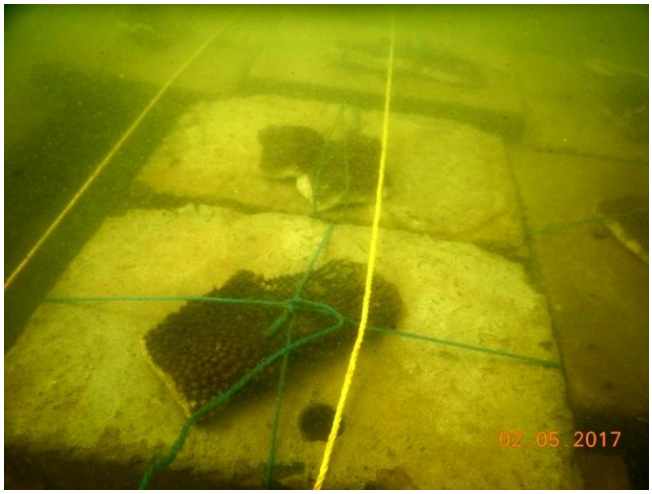


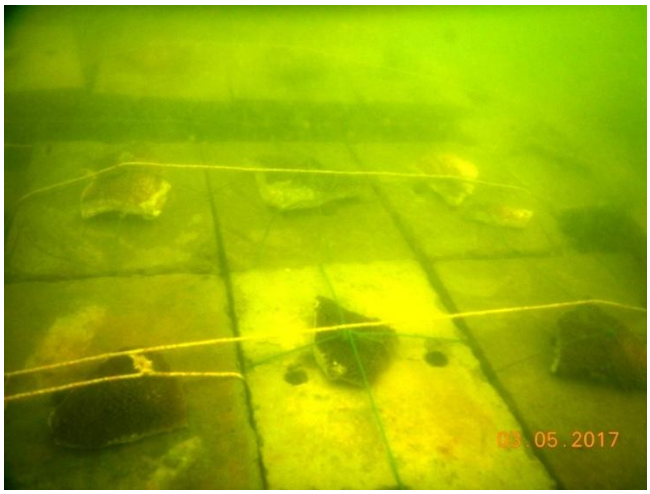
Transplanted concrete frames at Kavada rock

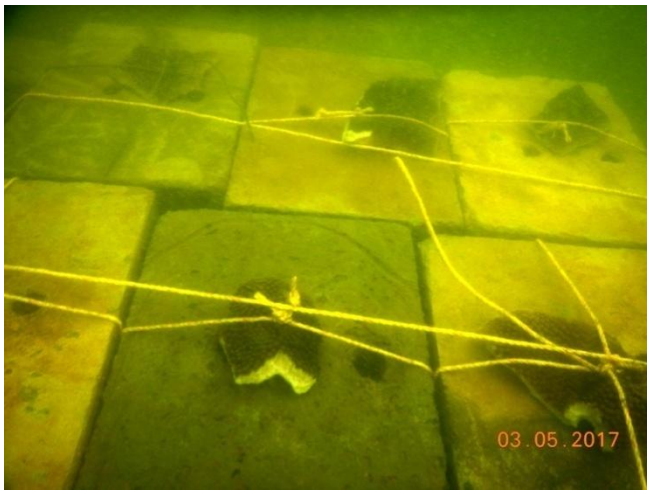




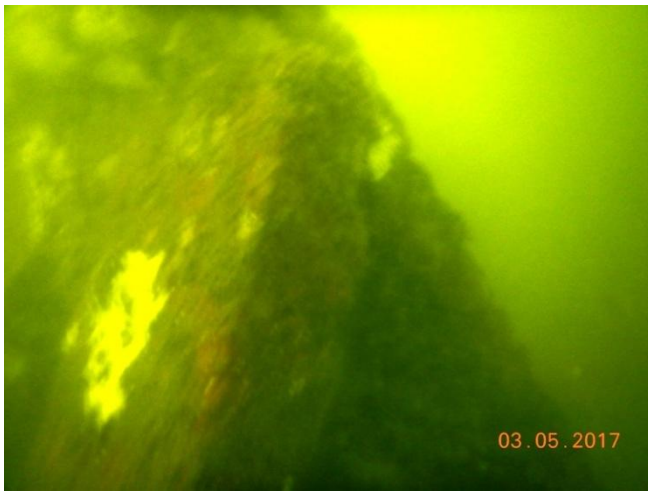


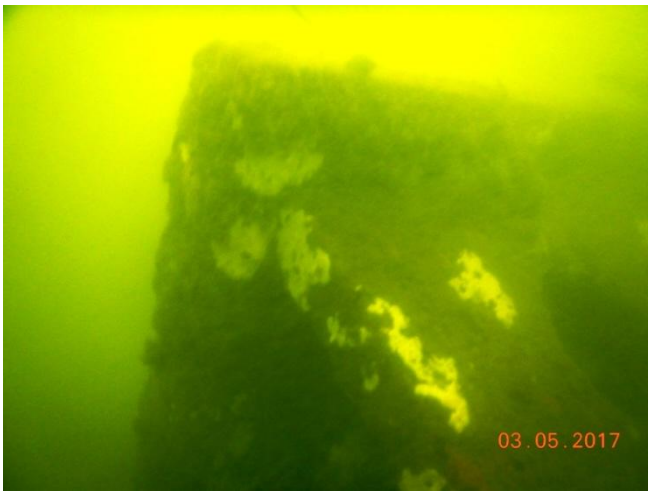


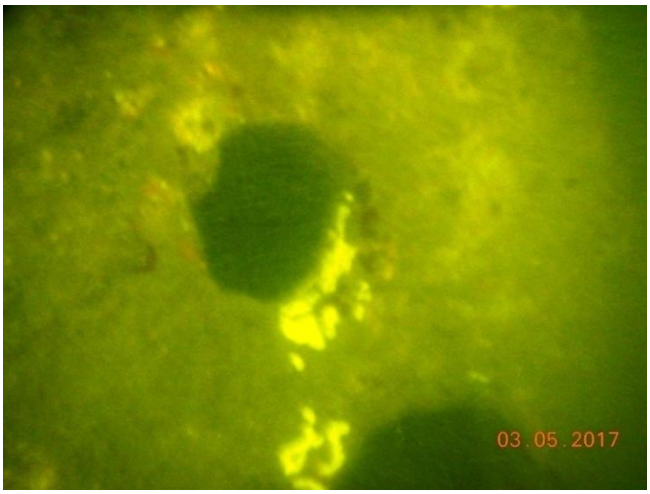




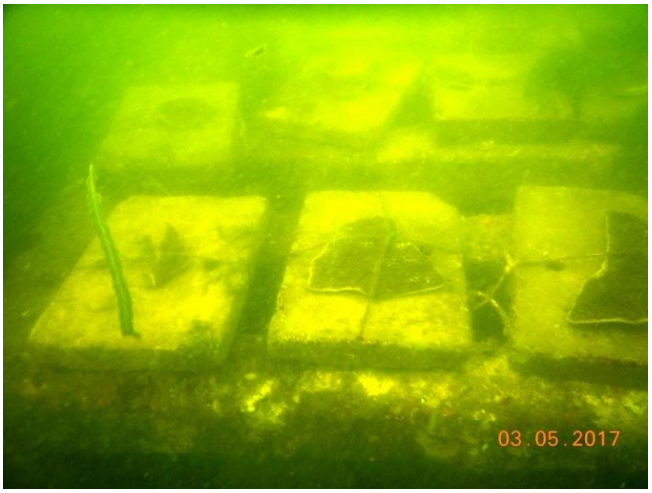
Artificial reefs at MMS

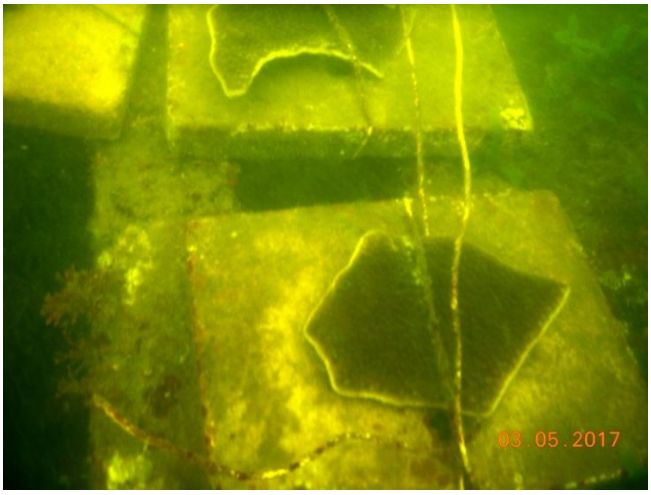






Transplanted frames at MMS





12. References

1. Done, T.J., R.A. Kenchington and L.D.Zell (1982). Rapid, large area, reef resources survey using a manta board. Proceedings of the 4th International Coral Reef Symposium, Manila, Philippines, 2: 597-600

2. Elwakeel, S.K. and J.P Riley, 1956. The determination of organic carbon in marine muds. *J. du. Conscil*, 22: 183-198.

3. English S, Wilkinson C, Baker V, (1997) Survey manual for tropical Marine resources. Australian Institute of Marine Science, Townsville Australia.

4. Qasim, S.Z. and M.V.M. Wafer (19790 Occurrence of living corals at several places along the west coast of India. Mahasagar - Bulletin of National Institute of Oceanography, 12: 53-58.

5. Strickland, J. D. H. and Parsons, T. R. (1972). A Practical handbook of sea water analysis, *Bull, 167(Fish Res. Bd. Canada, Ottawa)*, p 310.

Annexure - 1

प्रधान मुख्य वन संरक्षक (वन बल प्रमुख), महाराष्ट्र राज्य यांचे कार्यालय
Office of the Principal Chief Conservator of Forests (HOFF), Maharashtra State
वन भवन, रामगिरी रोड, सिविल लाइन्स, नागपूर ४४०००१ Van Bhavan Ramgiri Road, Civil Lines, Nagpur 440001
प्रधान मुख्य वन संरक्षक (वन्यजीव), महाराष्ट्र राज्य Principal Chief Conservator of Forests (Wildlife), Maharashtra State
pccfwlngp@mahaforest.gov.in; फोन Phone: 0712-2549563; फॅक्स Fax: 0712-2553018; वेबसाइट: www.mahaforest.gov.in

Sub:- Permission to carry out Coral rehabilitation at Malvan Marine Sanctuary site, Sindhudurg, Maharashtra.

No: Desk-22(8)/WL/Research/CR-21 (15-16) / **2597**/2015-16
Nagpur dated: **30th September, 2015**

To,
Dr. J.K. Patterson Edward,
Director,
Suganthi Devadason Marine Research Institute,
44-Beach Road,
Tuticorin-628 001
Tamilnadu (India)

Ref:- 1 The Chief Conservator of Forests, Mangrove Cell, Mumbai letter No. ADMIN/388, dated 26/8/2015

2 The Joint Director, (Wildlife) MoEF&CC, GoI, letter No.F.No.1-63/2015 WL dated 15th September, 2015

With reference to the Chief Conservator of Forests, Mangrove Cell, Mumbai letter dated 26th August, 2015 referred above, please find enclosed herewith a 'Permit to hunt for special Purpose'. This permit is for scientific management project entitled 'Studies on rehabilitation of Coral communities and setting up of artificial reef in Sindhudurg Cost, Maharashtra' and involves collection and transplanting of 5 Corals species (reef building corals: Order-Scleractinia) within Malvan Marine Sanctuary, Sindhudurg Maharashtra.

Encl:- As above

Principal Chief Conservator of Forests (Wildlife)
and Chief Wildlife Warden
Maharashtra State

Copy Submitted/Forwarded to :-

1. The Secretary (Forests) Revenue & Forest Department, Mantralaya, Mumbai-32
2. The Deputy Inspector General of Forests (Wildlife) GoI, MoEF&CC, Wildlife Division, 6th Floor, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi 110 003.
3. The Principal Chief Conservator of Forests (Research, Education & Training), Pune
4. The Additional Principal Chief Conservator of Forests (Research), Pune
5. The Additional Principal Chief Conservator of Forests (Wildlife) West, Mumbai
6. The Chief Conservator of Forests, Mangrove Cell, IInd Floor, A Wing, S.R.A. Nldg, Anant Kanekar Marg, Bandra (East), Mumbai-400 051.

New Folder permission to capture and radio-collar 2 Tigers Unred Karhandle and Pandharkawada Forest Division
1/4

FORM - II

[See Rule 9(6)]

PERMIT TO HUNT FOR SPECIAL PURPOSE

(Not Transferable)

Permit No. SPP-03/2015 dated **30th September, 2015 (See letter No. D-22(8)/WL/Research /CR-21/ (15-16)/** 2597/**15-16** dated **30th September, 2015)**

Name of National Park/Sanctuary : Malvan Marine Sanctuary, Sindhudurg Maharashtra.

Subject to the provisions of the Wildlife (Protection) Act, 1972 and the Maharashtra Wildlife (Protection) Rules, 2014 this permit is hereby granted to: -

1 Name of the permit holder : Suganthi Devadason Marine Research Institute, Tuticorin- 44-Beach Road, Tamilnadu (India) 628 001

2 Name of contact person in case of Institution/Organization : **Dr. J.K. Patterson Edward,** Director, SDMRI, Tuticorin, Tamilnadu

3 Postal Address :Taluka and District, Pin code Suganthi Devadason Marine Research Institute, Tuticorin- 44-Beach Road, Tamilnadu (India) 628 001

4 For period from : **01/10/2015 to 30/09/2016** (not exceeding one year) to hunt/collect the wild animals give in the table for the following special purpose.

(b) Scientific Research : Under the Project entitled 'Studies on rehabilitation of Coral communities an setting up of artificial reef in Sindhudurg Cost, Maharashtra' and involves collection of 5 Corals species (ree building corals: Order-Scleractinia) for translocation and rehabilitation within Malvan Marine Sanctuar Sindhudurg Maharashtra. The details are as follows:

Sr. No	Common name	Scientific name	Schedule of the Act	Sex and Number (include young ones)	Forest Range and Division	Location	Number to be released in natural habitat	Snake venom gm/ml
1	2	3	4	5	6	7	8	9
1	Reef Building Corals	*Turbinria mesenterina* (Order-Scleractinia)	Sch-I	1200 fragments each 8 cm length	50% (600 fragments) within Malvan Marine Sanctuary & 50% (600 fragments) outside the Sanctuary	Mangrove Cell Mumbai	All fragments will be transplanted for rehabilitation	Not relevant
2	Reef Building Corals	*Turbinria peltata* (Order-Scleractinia)	Sch-I	1200 fragments each 8 cm length	-do-			
3	Reef Building Corals	*Porites lichen* (Order-Scleractinia)	Sch-I	1200 fragments each 8 cm length	2 location in Malvan Marine Sanctuary			
4	Reef Building Corals	*Favites abdita* (Order-Scleractinia)	Sch-I	1200 fragments each 8 cm length	50% within Malvan Marine Sanctuary & 50% outside the Sanctuary			
5	Reef Building Corals	*Favites flexuosa* (Order-Scleractinia)	Sch-I	1200 fragments each 8 cm length	2 locations outside Sanctuary			

New Folder : Permit No. 3 permission Permit to hunt/collect 5 Corals species (reef building corals: Order-Scleractinia) .

2/4

Annexure 2

प्रधान मुख्य वन संरक्षक (वन बल प्रमुख), महाराष्ट्र राज्य यांचे कार्यालय
Office of the Principal Chief Conservator of Forests (HOFF), Maharashtra State
वन भवन, रामगिरी रोड, सिविल लाइन्स, नागपूर ४४०००१ Van Bhavan Ramgiri Road, Civil Lines, Nagpur 440001
प्रधान मुख्य वन संरक्षक (वन्यजीव), महाराष्ट्र राज्य Principal Chief Conservator of Forests (Wildlife), Maharashtra State
pccfwlngp@mahaforest.gov.in; फोन Phone: 0712-2549563; फॅक्स Fax: 0712-2553018; वेबसाइट: www.mahaforest.gov.in

Sub:- Permission to carry out Coral rehabilitation at Malvan Marine Sanctuary and Vengurla in Sindhudurg Cost, Maharashtra-reg.

No: Desk-22(8)/WL/Research/CR-21 (15-16) /4475/2016-17
Nagpur dated: 14th March, 2017

To,
Dr. J.K. Patterson Edward,
Director,
Suganthi Devadason Marine Research Institute,
44-Beach Road,
Tuticorin-628 001
Tamilnadu (India)
Email-director@sdmri.in

Ref:-
1 The Joint Director, (Wildlife) MoEF&CC, GoI, letter No.F.No.1-63/2015 WL dated 15th September, 2015
2 This office letter No. Desk-22(8)/WL/Research/CR-21(15-16)/2597/15-16 dated 30th Sept. 2015
3 Your letter No. SDMRI/CWLW Maharashtra/2015 dated 9th March, 2017

Please refer your letter dated 22nd February, 2017, regarding extension of permission for 6 months (01 Mar., 2017 to 31 Aug., 2017) to carry out coral rehabilitation at outside the Malvan Marine Sanctuary, Maharashtra at sr.no.3 above. Please find enclosed herewith a **'Permit to hunt for special Purpose'**. This permit is for scientific management project entitled **'Studies on rehabilitation of Coral communities and setting up of artificial reef in Sindhudurg Coast, Maharashtra'** and involves collection and transplanting of 5 Corals species (reef building corals: Order-Scleractinia) outside the Malvan Marine Sanctuary and identified for coral rehabilitation near Kavada Rock and donor coral site at Rock Garden, Sindhudurg Coast Maharashtra.

Encl:- As above

Principal Chief Conservator of Forests (Wildlife)
and Chief Wildlife Warden
Maharashtra State

Copy Submitted/Forwarded to :-

1. The Secretary (Forests) Revenue & Forest Department, Mantralaya, Mumbai-32
2. The Deputy Inspector General of Forests (Wildlife) GoI, MoEF&CC, Wildlife Division, 6th Floor, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi 110 003.
3. The Principal Chief Conservator of Forests (Research, Education & Training), Pune
4. The Additional Principal Chief Conservator of Forests (Research), Pune
5. The Additional Principal Chief Conservator of Forests (Wildlife) West, Mumbai
6. The Chief Conservator of Forests, Mangrove Cell, IInd Floor, A Wing, S.R.A. Nldg, Anant Kanekar Marg, Bandra (East), Mumbai-400 051.

New Folder permission to capture and radio-collar 2 Tigers Unred Karhandle and Pandharkawada Forest Division

1/6

FORM - II

[See Rule 9(6)]

PERMIT TO HUNT FOR SPECIAL PURPOSE

(Not Transferable)

Permit No. **SPP-14/2016** dated 14th **March, 2017 (See letter No. D-22(8)/WL/Research /CR-21/(15-16)/ 4475 /16-17** dated **14th March, 2017)**

Name of National Park/Sanctuary : Malvan Marine Sanctuary and Vengurla, Sindhudurg Maharashtra.

Subject to the provisions of the Wildlife (Protection) Act, 1972 and the Maharashtra Wildlife (Protection) Rules, 2014 this permit is hereby granted to: -

1 Name of the permit holder : Suganthi Devadason Marine Research Institute, Tuticorin- 44-Beach Road, Tamilnadu (India) 628 001

2 Name of contact person in case of Institution/Organization : **Dr. J.K. Patterson Edward,** Director, SDMRI, Tuticorin, Tamilnadu

3 Postal Address :Taluka and District, Pin code Suganthi Devadason Marine Research Institute, Tuticorin- 44-Beach Road, Tamilnadu (India) 628 001

4 For period from : **14/03/2017 to 31/08/2017** (not exceeding one year) to hunt/collect the wild animals given in the table for the following special purpose.

(b) Scientific Research : Under the Project entitled 'Studies on rehabilitation of Coral communities and setting up of artificial reef in Sindhudurg Coast, Maharashtra' and involves collection of 5 Corals species (reef building corals: Order-Scleractinia) outside the Malvan Marine Sanctuary and identified for coral rehabilitation near Kavada Rock and donor coral site at Rock Garden, Sindhudurg Coast Maharashtra. The details are as follows:

Sr. No	Common name	Scientific name	Schedule of the Act	Sex and Number (include young ones)	Forest Range and Division	Location	Number to be released in natural habitat	Snake venom gm/ml
1	2	3	4	5	6	7	8	9
1	Reef Building Corals	*Turbinria mesenterina* (Order-Scleractinia)	Sch-I	950 fragments each 8 cm length	63% (600 fragments) within Malvan Marine Sanctuary & 37% (350 fragments) outside the Sanctuary	Mangrove Cell Mumbai	All fragments will be transplanted for rehabilitation	Not relevant
2	Reef Building Corals	*Turbinria peltata* (Order-Scleractinia)	Sch-I	1250 fragments each 8 cm length	100% outside the Sabctuary-Rock Garden			
3	Reef Building Corals	*Porites lichen* (Order-Scleractinia)	Sch-I	1250 fragments each 8 cm length	100% outside the Sabctuary-Rock Garden			
4	Reef Building Corals	*Favites abdita* (Order-Scleractinia)	Sch-I	1250 fragments each 8 cm length	100% outside the Sabctuary-Rock Garden			
5	Reef Building Corals	*Favites flexuosa* (Order-Scleractinia)	Sch-I	1250 fragments each 8 cm length	100% outside the Sabctuary-Rock Garden			

New Folder : Permit No. SPP-14-2016 permission Permit to hunt/collect 5 Corals species (reef building corals: Order-Scleractinia) . 2/6

5. Species and Number of juvenile (young) specimens permitted to be hunted: None:
6. The wild animals will be released back in natural habitat **on the same day of its hunting.**
7. **The permit holder has paid fee of Rs. 6655/- (Rupees Six Thousand Six Hundred Fifty Five only)**
8. The conditions under which this permit is issued are as under :-

1. The permit holder shall submit a report of his collection as may be required by the Chief Wildlife Warden or authorized officer, and send a copy of such report to the Chief Conservator of Forests (Mangrove Cell) Mumbai of the area where hunting has taken place.
2. The permit holder shall produce the entire collection made by him for inspection, whenever required by the Chief Wildlife Warden or any other officer authorized by him for the purpose.
3. The permit holder shall not use any wild animal under this permit for any commercial purpose. Further, the permit holder shall not export his collection outside the State of Maharashtra, without the prior written permission from the Chief Wildlife Warden or any officer authorized by him in this behalf.
4. The permit holder shall submit quarterly report of hunting under this permit to the Authorized Officer. The report shall include details of inventory along with species (including scientific name), number and sex of wild animals hunted, juvenile specimens hunted, location of hunting and number of wild animals release back to its natural habitat as well as details of any wild animal inadvertently hunted by him during the period.
5. The permit holder shall surrender this permit to the Authorized Officer issuing this permit within 15 days of its expiry or before leaving the area given in the Permit, whichever is earlier, along with the final reports containing the details as required in the quarterly report.
6. No person other than the permit holder or his assistants engaged by the permit holder can use of this permit. The permit holder shall communicate names of his assistants at least three days in advance to the Authorized Officer, whose direction on dissociating any individual from use of this permit shall be binding. The permit holder is prohibited from subletting, outsourcing or transferring this permit in any manner. This permit is not transferable by inheritance or any other means of similar nature.
7. The permit holder shall abide by additional conditions, if any appended to this permit, as deemed fit by the Chief Wildlife Warden or Authorized Officer while issuing this permit.
   See annexure-I of this permit for additional conditions.

The Government of India, Ministry of Environment, Forest and Climate Change has given due approval vide letter No. F.No.1-63/2015 WL dated 15th September, 2015.

Enclosure :- Annexure-I

Place :- Nagpur

Dated :- **14th March, 2017**

Principal Chief Conservator of Forests (Wildlife)
And
Chief Wildlife Warden
Maharashtra State

New Folder : Permit No. SPP-14-2016 permission Permit to hunt/collect 5 Corals species (reef building corals: Order-Scleractinia) , 3/6

ANNESURE-1 TO PERMIT TO HUNT FOR SPECIAL PURPOSE

Permit No. **SPP-14/2016** dated **14th March, 2017 (See letter No. D-22(8)/WL/Research /CR-21/(15-16)/ 4475 /16-17 dated 14th March, 2017)**

Name of National Park/Sanctuary/Place : Malvan Marine Sanctuary, Sindhudurg Coast, Maharashtra.

Permit to hunt/collect 5 Corals species (reef building corals: Order-Scleractinia) for translocation and rehabilitation purpose under the project entitled 'Studies on rehabilitation of Coral communities and setting up of artificial reef in Sindhudurg Coast, Maharashtra'.

Additional conditions with reference to item no. 8 (7) of the permit are as follows:

1. The collection and transplantation would be made in the presence of the representative of Forest Department.
2. Only the barest minimum quantity required for the research study would be collected and transplanted.
3. No damage to be caused to other wildlife.
4. The findings of the study be shared with both, the central government and the state wildlife department.
5. In case of any mis-happening during the process, that endangers or may endanger the safety of the corals, the central government or the Chief Wildlife Warden, Maharashtra State may review/revoke the permission given.

The permit holder shall promptly share information generated by activities carried out under this permit.

Nagpur

Dated :- **14th March, 2017**

Principal Chief Conservator of Forests (Wildlife)
and
Chief Wildlife Warden
Maharashtra State

New Folder : Permit No. SPP-14-2016 permission Permit to hunt/collect 5 Corals species (reef building corals: Order-Scleractinia) , 4/6

Annexure 3

Coral Rehabilitation Training Manual

1. Introduction

Coral reefs are the most diverse marine ecosystems with rich biodiversity and are known for their beauty, diversity and productivity. Coral reefs are justifiably termed as rain forests of the ocean. The value of coral reefs has been estimated as much as 30 billion U.S. dollars each year, providing food, protection of shorelines, jobs based on tourism, and even medicines (Cesar et al, 2003). Coral reefs produce the framework that support thousands of marine species including crabs, worms, snails, lobsters, and the myriad of fish species that humans depend on for subsistence, commercial and recreational fishing (Moberg and Folke, 1999). Coral reefs protect shorelines from wave action and prevent erosion and property damage and reefs also provide beach sand and protect the highly productive wetlands along the coasts. Coral reefs have declined over the course of human history, culminating in the dramatic increase in coral mortality and reef degradation of the past 20-50 years (Pandolfi et al., 2003). The causes of this degradation are a complex mixture of direct human-imposed and climate-related stresses, and include factors such as outbreaks of disease.

Loss of healthy coral reefs would cause extinction of thousands of marine species as well as removal of a primary source of food, income and employment for millions of people around the world. Many coral reefs are under severe pressure from anthropogenic disturbances like coral mining, dredging, sewage, chemical pollution, oil spills, ship grounding, chemical and thermal pollution, euthropication etc. Also, strained by low fish catches, fishermen are often compelled to use more effective and also more destructive fishing methods, such as for example dynamite fishing and seine nets, reducing the productivity of the coral reefs even further (Lindahl, 2003). Moreover, as a result of the elevated sea surface temperature along with the strong El Nino during 1998, 2010 and during 2014-16, a significant portion of corals were killed globally (Hughes et al., 2016). It is feared that the global warming and consequently the elevated sea surface temperature and El Nino events would increase in the coming years causing severe threat to coral reefs worldwide. To tackle the causes of coral degradation, proper coastal management activities are very important both to reduce further damage and to allow the coral reefs to recover. Further, there are many restoration techniques by which corals can be restored faster than their natural recovery. Coral degradation is measured by the reduction in live coral cover. We can restore the degraded coral reefs by increasing the live coral cover with any suitable rehabilitation method.

Suganthi Devadason Marine Research Institute (SDMRI), Tuticorin is the first institution to pioneer the reef rehabilitation efforts in India with a great success. SDMRI has standardized the viable low-tech and low cost reef rehabilitation techniques for large-scale restoration work (Edward et al., 2005, 2006) including substrate and coral fragment size. Further, SDMRI has succeeded in deploying artificial reef structures for fishery enhancement and coral attachment. The methods are low-cost and give long-lasting results such as increased live coral cover, coral recruitment, fishery enhancement and stable substratum.

2. Coral reefs in India

India has four major reef areas (Gulf of Mannar and Palk Bay, Gulf of Kachchh, Lakshadweep and Andaman and Nicobar Islands). The total reef area in India is estimated to be 2,375 sq km. Fringing reefs

are found in the Gulf of Mannar and Palk Bay in Tamilnadu. Platform reefs are seen along the Gulf of Kachchh in Gujarat. Patch reefs are found near Ratnagiri and Malwan coasts of Maharashtra. Atoll reefs are found in the Lakshadweep archipelago. Fringing and barrier reefs are found in Andaman and Nicobar islands. Due to the highest freshwater flow through a large number of rivers mixing with the Bay of Bengal, there are no significant coral reef formations on the east coast of India. Satellite imagery shows scattered patches of corals in the inter tidal areas and occasionally at sub tidal depths down to a few meters along the west coast of India, notably at Ratnagiri, Malwan, Rede Port and Vizhingam. All major coral reef areas in India, including the Gulf of Mannar, Lakshadweep, Andaman and Nicobar Islands, and the Gulf of Kachchh are under threat from human activities.

3. Coral reefs in Malvan

Malvan coast in Maharashtra is one of the important tourist attractions in the west coast of India which is marked by islands, rocky areas and sandy beaches. Corals in Malvan have been reported to be attached to the rocks and are dominated by *Porites* spp. (Qasim and Wafar, 1979) Malvan marine sanctuary (MMS) encompassing an area of 29.22 sq.km was declared in 1987 by Maharashtra Government in order to protect the coral patches and other important marine ecosystems. MMS occurs in Malvan Taluka of Sindhudurg district along the Maharashtra coast between 16°15'-16°50' N latitude and 73°27'-73°31' E longitude (Singh, 2003; Barman et. Al., 2007). In Malvan coast, tourism and fishing are the main source of the income for the local fishermen (Kalyan De et al., 2015). The amount of corals in Malvan is comparatively lesser than the other major coral reef areas of India. But, with the low-cost transplantation techniques, coral cover in this region can be increased significantly.

4. Coral rehabilitation

Corals being animals can reproduce sexually and asexually. Transplantation of corals is based on the asexual reproduction of corals through fragmentation. If a fragment of coral colony is broken from the donor colony and finds a suitable substrate and environmental conditions, it can grow as a separate colony. The term coral transplantation refers to the transplantation of coral fragments onto artificially made substrates deployed underwater. Transplantation of coral fragments has been considered a useful technique for restoring coral reefs. This technique has been suggested to help the corals recover from the degradation and to extend the reef area by increasing the live coral cover. Several restoration experiments have revealed that the use of coral fragments may serve as a good tool for reef rehabilitation. The primary objectives of coral transplantation are to improve (i) reef quality in terms of live coral cover, (ii) biodiversity and (iii) topographic complexity (Edwards, 1998). The technology for the transplantation should be cost-effective for the wide-scale rehabilitation.

4.1. Coral rehabilitation substrates

Identifying and designing proper artificial substrates is the major factor for the success of coral rehabilitation. Concrete artificial structures have been reported to be highly successful in any underwater environment. Main reason for this success is the strong compatibility of the material with the environment in which it is deployed. Moreover, concrete is generally very durable and stable to the seawater exposure. Such structures have been designed by SDMRI after several experimentations in Gulf of Mannar. Concrete frames of 1m X 1m X 0.25m size was experimented in Gulf of Mannar with very good results. These concrete frames are deployed in the selected sites first and are arranged in order under the water. Onto these concrete frames, cement slabs of 20 cm X 5 cm X 15 cm are used for

fixing the coral fragments before being placed on the deployed concrete frames. The concrete frames and slabs are constructed using ferro-cement.

4.2. Site selection for coral rehabilitation

To get a good result in restoration, selection of the ideal sites is the key factor. Major considerations in the selection of a restoration site are the general conditions for coral growth, availability of donor corals and distance to the rehabilitation site. The physical conditions required for coral rehabilitation are accessibility to the site, preferably protected against strong wave action and clear water, salinity between 32 and 36 ppt and water temperature above 24º C (for faster growth temperatures above 29º C are recommended) to a maximum of 30º C. The vicinity of the rehabilitation site should be free from freshwater inflow of rivers. Freshwater run-off after a heavy downpour should not be a problem if the site is more than 100 meters from the shore without extensive reef flat. If the rehabilitation is planned close to urban and/or industrial settlements, the impact of pollution should be assessed. Even if an area appears to be suitable for the restoration because of other considerations, priority should be given on reefs with natural abundance of corals since this will guarantee that the abiotic conditions are met.

4.3. Donor site

As much as possible a reef with donor potential should be found in the vicinity of the proposed transplantation site, not more than 10 nautical miles and can be reached within 30 min by boat to minimize the stress of the coral fragments caused by long transport. Prior to restoration, a survey should be conducted to assess the abundance and diversity of the donor site. Donor site should be selected where the corals are comparatively healthy and have a good live coral cover to act as a donor site.

4.4. Transportation of substrates

Each substrate weighs about 80-100 kg in order to maintain the stability. The substrates can be transported from the place of construction to the shore by tractors during low tides. From the seashore, the substrates are transported to the restoration and deployment sites using a raft made of bamboo sticks or a floating jetty which can accommodate up to 5 tons. The raft or floating jetty should be pulled by a mechanized trawler. If raft and floating jetty or not available, the substrates can be transported with mechanized trawlers or a barge.

4.5. Deployment of substrates

After reaching the rehabilitation site, concrete frames are placed at the ocean bottom with the help of ropes tied with the frames. After placing all the frames, scuba divers get in to the water to arrange them and they have to check whether any damages in the frames. Tilted frames are arranged in proper order for the transplantation. Frames are arranged with an interval of 1 to 2 meters from each other for paving way for the coral growth without difficulties. After arranging the frames, they can be numbered or tied with each other with ropes for continuous monitoring.

4.6. Selection of species

Species selection for coral rehabilitation is also very critical as it the species involved should increase the live coral cover. Transplantation should be done only with the native species and not from a

different reef region where the environmental conditions are totally different. The selected species should be abundant in the donor site and should be healthy. The species which are resilient to bleaching events or disease outbreaks would be preferable for transplantation. Fast growing species such as *Acropora, Montipora* and *Turbinaria* are good for transplantation as the results are imminent and increase in the live coral cover will be fast.

4.7. Collection of fragments

The fragments of targeted corals are collected underwater from a site with high coral cover. Collection of fragments should be done in the morning to be able to complete the work and deploy the fragments to their designated transplantation as soon as possible. Collection of fragments involves scuba divers. The direction of collection should start always opposite the current direction so the return to the boat with the fragment filed basket will be easy and safe. Fragmentation should not exceed 3-5% of the colony size to reduce the stress to the donor colony. Hammer and chisel are used for the fragmentation under the water. The removed fragments are taken to the boat using plastic baskets then are transferred to a big plastic tubs with sea water.

4.8. Transportation of collected fragments

Precision and care should be taken during fragmentation and transportation of fragments from the donor site. On the boat, collected fragments are immediately transferred to big plastic tubs with seawater and are given aeration with portable aerators. The plastic tubs with coral fragments are covered by clothes to avoid direct sunlight and are transported immediately to the rehabilitation site. A good indicator for the stress levels of fragments is the mucus production of polyps. Sea water in the tubs should be changed at regular intervals in order to reduce the stress and the level of temperature and salinity are monitored. Change of water must be done very carefully by pouring the water along the side of the tubs rather than directly on the corals.

4.9. Tying of coral fragments on cement slabs

Tying of the coral fragments can be done during the transportation. Before the fragments are tied, ferro cement slabs (Size at 20 cm X 5 cm X 1.5 cm) are washed with seawater. Collected coral fragments are further fragmented to desirable size (>8 cm size) using a bone cutter. Generally, it is expected that the larger fragments have the higher survival rate. Each fragment is attached onto a cement slab in a horizontal orientation. If possible, largest part of the fragment should be in contact with substrate and most of the polyps are oriented upward in vertical position of the fragment. A nylon rope should be placed snugly around the fragment and firmly tightened at the side of the substrate. The fixed fragments are then transferred to a fresh sea water tub. It is recommended to place heavy and sturdy fragments first in the containers followed by the more fragile ones on top.

4.10. Deployment of fixed fragments

After reaching the rehabilitation site, the fragments tied with the cement slabs are immediately taken into the water in plastic trays by the scuba divers for transplantation. Before the fragment is released into the water, attachment must be checked manually for the firm attachment. If the water is very shallow skin dive is enough for deploying the fragments. The slabs are arranged over the frames with approximately 5 cm gap from each other. Then the slabs are tied with the frame with the help of nylon ropes to ensure that they are not dislodged by the waves and currents.

4.11. Monitoring and maintenance

Basically monitoring of transplanted corals is performed in each season, and it is necessary to add a monitoring at the first month immediately after transplantation, where corals are unstable. For scientific assessment of transplantation, the transplanted communities should be compared with natural communities after five years. When monitoring transplanted corals, it is necessary to monitor their habitat environment at the same time to understand it as one of several factors affecting coral survival. The important environmental factors that can affect the survival of corals are water temperature, water movement, sedimentation and predators.

4.11.1. State of survival and death of corals

Corals can be classified as follows according to the state of the transplanted coral colonies; healthy corals, partially dead corals, partially alive corals, very small number of corals alive, no corals alive and disappeared. If the colour of polyps and coenosarc is normal, no abnormality in extension of tentacles, and not covered with much mucous membrane, the transplanted colonies are considered as good in condition. If the polyps and coenosarc are bleached, the surface is covered with much mucous membrane, or dead area is expanded by the abnormal growth of algae and sea sponge, the transplanted colonies are considered as bad in condition.

4.11.2. Removal of algae and predators

Marine algae can attach to the artificial substrates and because of the fast growth rate the algae may suffocate the corals and kill them. Hence, it is necessary to monitor and remove the algae frequently. A coral dominated area can become algal dominated area very fast and such phenomenon is called coral-algal phase-shift. Such phase-shift has been reported in many reef regions and hence the removal of algae is very important to maintain a good reef ecosystem. The monitoring is also necessary when organisms eating corals, such as coral-eating gastropods, crown of thorns, corallivorous fishes, bio-eroding sponges, etc. are distributed around the transplantation area.

4.11.3. Removal of fishing nets

Fishing nets if any are found entangled to the concrete frames and transplanted corals, they must be removed immediately as they would keep on damaging the corals mechanically. Other mechanical damages such as anchoring, boat grounding, etc. should be monitored and cleared immediately.

4.11.4. Survival and Growth rate

Survival of the coral transplants is the prime and utmost step in the success of any coral transplantation activity. II a successful transplantation project, transplanted corals will survive and grow in a manner similar to that of naturally occurring corals. Transplanted corals are identified to species level and survival and growth rate are monitored monthly. The growth rate of a colony is highly variable. It depends on the species and may fluctuate significantly within an individual colony and from month to month. Vernier caliper with flexible scales or an underwater measuring tape can be used to measure the greatest diameter and greatest length of the fragments. The survivorships of the coral transplants, expressed in terms of the percentage number of living ones can be recorded monthly, quarterly, half-

yearly and annually. It is important to monitor how the transplanted or relocated corals survive over time for evaluation of the techniques and results of transplantation.

4.11.5. Monitoring for bleaching and disease outbreaks

Global warming triggered elevated sea surface temperature and El nino have become common nowadays and cause widespread coral bleaching. Hence signs of bleaching should be observed carefully on the transplanted coral colonies. Bleached corals look white but have the polyps intact. Bleaching can also be caused by sedimentation and other stressors. Frequency and intensity of coral disease outbreaks have increased over the years. Hence, transplanted coral fragments should be checked for disease outbreaks. Unlike bleaching, diseased corals show distinct lesions.

4.11.6. Water quality analysis

The detailed data on water quality conditions and weather has to be collected from the study area from the month of deployment of substrates. The physical and chemical properties of the water at the study site should be measured regularly for possible correlation with any changes observed on the reef. Most coral species can survive only within narrow salinity and temperature ranges, and any marked changes in parameters such as light transmission, sedimentation, and dissolve oxygen may affect the growth or survival of transplanted corals. The data on water quality parameters such as temperature, salinity, turbidity, dissolved oxygen and nutrients have to be collected regularly from the rehabilitation site by random sampling.

Recent concern over widespread bleaching and its possible association with high water temperatures, along with more general concern over global warning have increased the interest in water temperature data from coral reef environment. Digital thermometer readings just below the water surface (30cm) and at the depth of transplanted site are to be measure. Dissolved oxygen is necessary for the survival of transplanted coral colonies and other associated resources. Low level of dissolved oxygen may indicate high bacterial concentrations. Salinity of the water may be subjected to fresh water influx or high salinity and warm water from water-making facilities. Salinity can be measured easily with a handy refractometer. Ph of the water is unlikely to vary much over time, but changes may indicate that the reef is being affected by a new source of pollution. The pH measurement is taken by using pH paper or PH meter. Turbidity and total suspended solids should also be studied with standard protocols.

The amount of light available for photosynthesis of free-living and symbiotic algae affects the growth of corals and other organisms. Hence using a secchi disc, vertical visibility of the water is measured. Corals and other organisms require some amount of nutrients such as calcium, magnesium, nitrates, nitrites, chlorides, etc. Increases can lead to changes in the relative abundance of organisms such as macro algae or bacteria. Hence, sea water collected from the rehabilitation site should be analysed for nutrients using standard protocol.

4.11.7. Benthic community structure

The success of coral rehabilitation can be measured by assessing the changes in the benthic community structure. Benthic community structure includes all the sessile benthic organisms. By assessing the benthic community structure at regular intervals, it will be understood whether live coral cover is increasing. Increase in the live coral cover directly indicates the success of coral transplantation.

Apart from the live coral cover, percentage cover of algae and other organisms would provide information about whether the rehabilitation site is in a good condition. Benthic community structure is assessed using line intercept transect method, belt transect method and quadrat method involving scuba diving.

4.11.8. Fish abundance

Fishes may respond to various aspects of habitat structure which is reflected in their density and diversity. The structural complexity of a habitat is a major factor for the abundance and diversity of the fish communities. When the transplanted corals grow and increase the habitat complexity, fish abundance increases and thereby indicate the success of coral rehabilitation. To assess the fish communities, underwater fish visual census applying belt transect method is used.

4.11.9. Epifauna

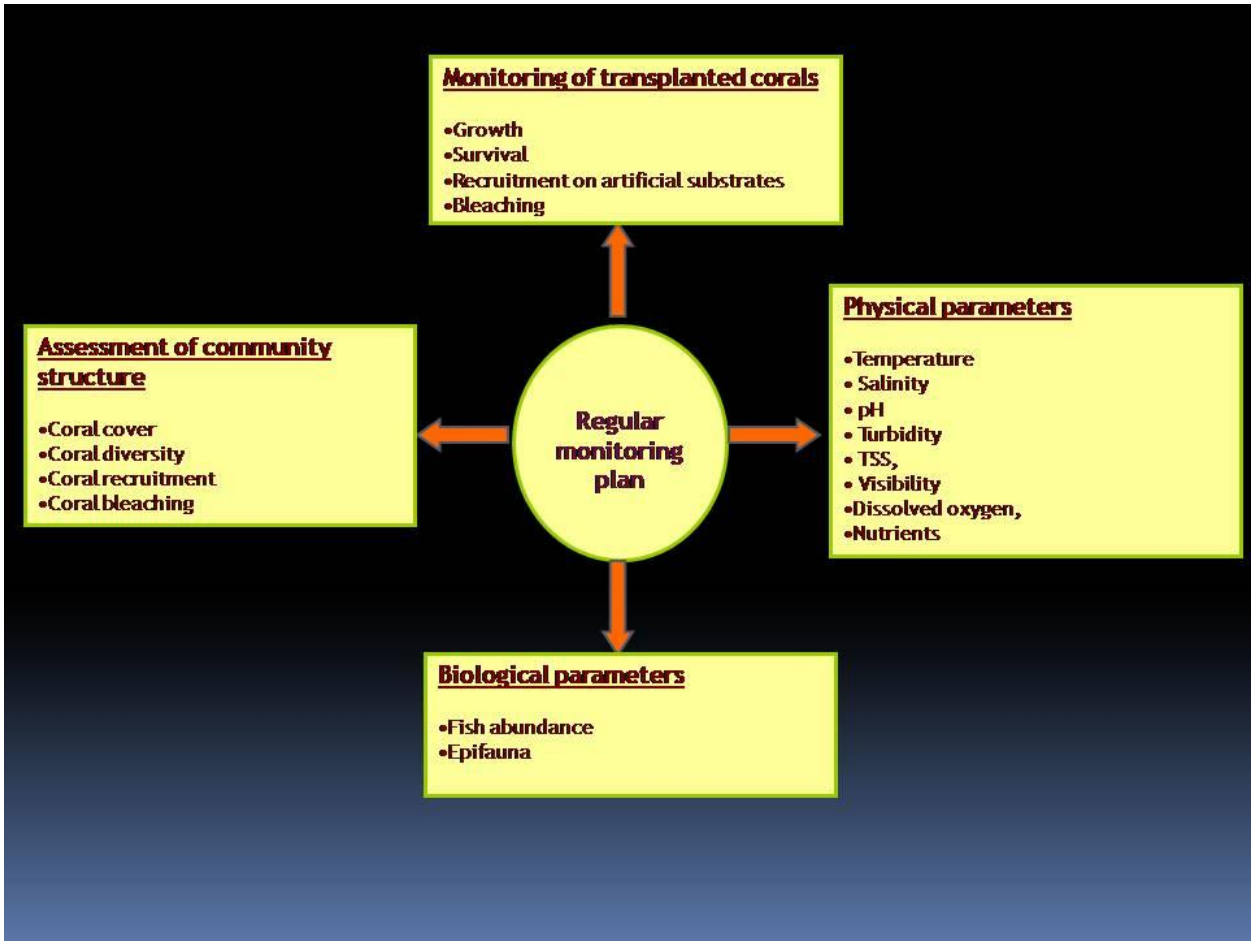
The species composition and epifauna cover on the transplanted substrates have to be recorded by visual observations and collection of samples. Epibenthic invertebrates could be surveyed using quadrat method and samples have to be collected from the reef surface and identified.

4.11.10. Spawning monitoring

The speed of growth and survival rate should be thought of as more important than mere regeneration with regard to the transplantation of coral fragments, but if the transplanted corals can spawn, that should contribute more to the recovery of total coral reefs because the coral supply source is increased. Since the possibility of the spawning is increased as the transplanted colonies grow, monitoring should be carried out when the nearby natural corals spawn. Though time of spawning varies from year to year and among the various waters, it is known that many species usually spawn around the full moon in early summer night. Therefore, it is desirable to monitor the spawning by continuously monitoring the polyps.

4.11.11. Natural coral recruitment

The larval supply of coral species need to be examined by estimating the number of new corals settling on transplanted substratum, which should be assessed at regular intervals. 1x1 m quadrats are used to study the coral recruitment pattern.



5. References

1. Barman, R.P., Mukherjee, P. and Das, A. 2007. On a collection of fishes from the Malvan Marine Sanctuary, Malvan, Maharashtra, India, 2007, *Records of zoological survey of India,* 107(Part-1): 71-87.
2. Cesar, H., Burke, L. and Pet-Soede, L. 2003. The economics of worldwide coral reef degradation. Cesar Environmental Economics Consulting and WWF-Netherlands, Arnhem and Zeist, The Netherlands. pp23.
3. Edward, J.K.P., Patterson, J. and Mathews, G. 2006. Restoration techniques for conservation and management of coral reefs. In: Training manual of the national training workshop on Marine and Coastal Biodiversity Assessment for Conservation and Sustainable Utilization: 280-286.
4. Edward, J.K.P., Patterson, J., Mathews, G. and Wilhelmsson, D. 2005. Awareness raising and feasibility of reef restoration, through coral transplantation in Tuticorin, Gulf of Mannar, India. Coral Reef Degradation in the Indian Ocean (CORDIO) – Status Report 2005: 243-251.
5. Hughes, L., Steffen, W., Rice, M. 2016. Australia's coral reefs under threat from climate change, Climate Council of Australia Ltd., pp 22.
6. Kalyan De, Sautya, S., Mote, S., Tsering, L., Patil, V., Nagesh, R. and Ingole, B. 2015. Is climate change triggering coral bleaching in tropical reef? *Current Science,* 2015, 109(8): 1379-1380.

7. Lindahl, U. 2003. Coral reef rehabilitation through transplantation of staghorn corals: effects of artificial stabilization and mechanical damages. *Coral Reefs,* 22: 217-223.
8. Moberg, F., and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics*, 29(2): 215-233.
9. Pandolfi, J. M., Bradbury, R. H., Sala, E., Hughes, T. P., Bjorndal, K. A., Cooke, R. G., McArdle, D., McClenachan, L., Newman, M. J. H., Paredes, G., Warner, R. R. and Jackson, J. B. C. 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science,* 301: 955-958.
10. Singh, H.S. 2003. Marine protected areas in India, *Indian J. Mar. Sci.,* 32(3): 226-233.

Annexure 4

Coral Rehabilitation Training Manual (in Marathi – DRAFT)

परिचय

प्रवाळरीफ हे सौंदर्यपूर्ण, वैविध्यपूर्ण आणिउपजाऊसागरीपरीसंस्थांपैकी एकआहे. त्यांनासागरातीलवर्षावन असेच संबोधले जाते. तेआपल्याला अन्न, आपल्याकिनारयाचे संरक्षण, पर्यटन आणि ओषधेसुद्धादेतात; ह्यासर्वांचेअंदाजे मुल्यांकन ३०अब्जअमेरिकी डॉलर एवढे आहे[1]. याशिवाय हि रीफ्स लाखोसजीवांनाजगता येईल असेपूरकपर्यावरणनिर्माण करूनत्यांचेपालन-पोषणकरतात, ज्यातखेकडे, शंख-शिंपले, शेवंड, आणिअनेक मासेसुद्धाआहेत. ह्यासर्वांवर समुद्र-किनारयावरीलमाणसांचा आहार, मत्स्य-उद्योग, पर्यटनअवलंबूनआहे[2]. कोरलं रीफवाळूनिर्मिती करून किनार्यांचीधूप थांबवतात, समुद्रकिनाऱ्यांचीधूप, मोठ्यालाटांपासूनसंभवणाऱ्या धोक्यापासून होणाऱ्यामालमत्तेचेनुकसान तसेच जास्तउत्पादकता असलेल्यादलदलीच्या किनारीप्रदेशांचेसंरक्षण करतात. मागच्यावीस तेपन्नास वर्षाच्यामानवीइतिहासातप्रवाळच्याकत्तलीमुळेकिवाप्रवाळ रीफ परीसंथ्स्थेतील बदलामुळेप्रवाळरीफचेक्षेत्र लक्षणीयप्रमाणात कमी होतआहे.मानवी जीवनामुळेहोणारेपर्यावरणातील बदल, तसेचजागतिकपर्यावरणीयबदल (त्यामुळेहोणारेपरिणाम) आणिप्रवाळना होणारेरोग.

निरोगी प्रवाळभिंती नष्ट होत असल्यामुळेहजारोसागरीजलचरप्रजाती विलुप्त होऊघातलेल्या आहेत तसेचलाखोमाणसे जीह्यापरिसंस्थेवरअन्न, उत्पन्न आणिमिळकतीचेसाधनम्हणूनअवलंबूनआहेत त्यांच्यावर परिणामहोईल. मानवीहस्तक्षेप जसे कीप्रवाळखडकांचे उत्खनन,सांडपाणी वरासायनिकप्रदूषण, तेलाचेतवंग, गरम पाण्यामुळेहोणारेप्रदुषण यामुळेअनेकरीफ्सवरमानवीतणावपडत आहेआणि त्यांचेसंतुलनबिघडतआहे . यासर्व गोष्टींसकट कमीहोणाऱ्या मत्स्यउत्पादनामुळे मासेमारीसाठी नवनवीन, अधिकपरिणामकारकआणि अधिकघातकअशामासेमारीच्या पद्धती विकसितकरण्यात आल्या आहेत, उदा. डायनामाईट मासेमारी, पर्ससीन नेट जेकोरलंरीफच्याउत्पादकतेवरअजूनचपरिणामकरतात.याच्या व्यतिरिक्त, 1998, 2010 आणि 2014-16 दरम्यान मजबूत अल -निनोसह समुद्राच्या पृष्ठभागाचे तापमान वाढल्याने,याचागंभीरपरिणामप्रवाळभित्तीवरझालाआणि प्रवाळ भित्तीचेएक मोठा भाग लोप पावला (ह्यूजेस एट अल., 2016).

जागतिक तापमान वाढ , समुद्र-पृष्ठावरील तापमानआणि अल-निनोचीवाढणारी वारंवारतायामुळेजगभरातीलप्रवाळभित्तीचे येत्या काही वर्षात प्रचंड नुकसान होणार आहे . किनारपट्टीचे योग्य नियोजन आणि व्यवस्थापन, प्रवाळ भित्तीचे होणारे नुकसान करण्यासाठी तसेच परिस्थिती सावरण्यासाठी मदत करेल .याशिवाय, इतर अनेक अश्याअनेकपद्धती आहेत

[1] Cesar et al, 2003

[2] Moberg and Folke, 1999

ज्याद्वारेप्रवाळभित्ती नैसर्गिक पुनर्प्राप्तीपेक्षा जलदगतीनेसावरू शकतात. निकृष्ट दर्जाचे प्रवाळ हे जीवित प्रवाळाच्या विस्तारामध्ये झालेल्या कमतरतेच्या आधारे मोजले जाते. आपणकोणत्याही पद्धतीने जीवित प्रव ळांचाविस्तार वाढवून कोणतेही खराब झालेले प्रवाळ भित्तीचे पुनर्वसन करू शकतो.

सुगंथी देवदासन मरीन रिसर्च इन्स्टिट्यूट (एस .डी.एम.आर.आय.), तुतीकोरीन हि भारतातील प्रवाळ भित्तीचे कुर्त्रीम्रीत्या पुनर्वसन करणारीपहिली संन्स्था आहे आणि त्यांनी अनेक प्रकल्प पूर्ण केले आहेत . एस .डी.एम.आर.आय. ने आपल्याकडे वापरण्या योग्य असे स्वस्त, कमीतांत्रिकगरजाअसणारेकृत्रिम प्रवाळ भित्तीचे पुनर्वसन करण्याचे तंत्रज्ञान विकसित केले आहे जे मोठ्या प्रमाणातीलप्रवाळ-पुनर्वसनप्रकल्पात वापरता येऊ शकतात (एडवर्ड आणि इतर २००५, २००६). एस .डी.एम.आर.आय. ने निर्मिलेल्या आणि समुद्रात सोडलेल्या कृत्रिम प्रवाळभित्तीमुळे मत्स्यौत्पादनात वाढ आणि प्रवाळाच्या नैसर्गिक वाढीसाठी जागामिळाली. हे तंत्रज्ञान कमी खर्चिक आणि तांत्रिकबाबीब्वर आधारित असून तेअनेक वर्षांपर्यंत टिकेल असे परिणाम करते उदा. जिवंत प्रवाळांचे क्षेत्र वाढवणे, त्यांचेप्रजोत्पादन, मत्स्योत्पादानात वाढ आणि पूरक असा अधिवास निर्माण करणे.

भारतातील प्रवाळभित्ती

भारतात चार प्रमुखप्रवाळांच्याजागा आहेत, मन्नारचे आखत, पाकचा उपसागर (Palk Bay) , कच्छचे आखत, लक्षद्वीप आणि अंदमान-निकोबार बेट समूह. सर्वमिळून भारतातील प्रवळांचेक्षेत्रहे 2375 चौ. किमी आहे. फ्रीन्जिंग प्रकारातील प्रवाळभित्ती हेतामिळनाडूतील मन्नारचे आखत, पाकचा उपसागर (Palk Bay) तर प्लाटफोर्म प्रकारातील प्रवाळभित्ती गुजरातच्याकच्छच्या आखतात आढळतात. महाराष्ट्रातील मालवण आणि रत्नागिरीत प्रवाळभित्ती अनेकतुकड्यांच्यास्वरुपात पसरलेले आहेत. अटोल प्रकारातील प्रवाळभित्ती फक्तलक्षद्वीप बेट समूहात आहेत आणि फ्रीन्जिंगव बर्रीअर प्रकारातीलप्रवाळभित्ती अंदमान निकोबार बेट समूहातआहेत. अनेक मोठ्या नद्या आणि त्यंच्या गोड्या पाण्याच्या प्रवाहामुळे भातार्ताच्या पुर्व किनारपट्टीवरप्रवाळभित्तीचे प्रमाण कमी आहे.उपग्रहावरून घेतलेल्या छायाचित्रांच्या आधारावर पश्चिम किनारपट्टीवर महाराष्ट्रातीलरत्नागिरी, मालवण, रेड्डी आणिकेरळातील- विझीन्गमजवळ प्रवाळभित्ती अनेकतुकड्यांच्यास्वरुपात परारलीआहे. भारतातीलसर्वच प्रवाळभित्ती विविधमानवीकृत्यांच्या परिणामामुळे अडचणीत आल्या आहेत.

मालवण मधील प्रवाळभित्ती

मालवण, महाराष्ट्र हेपश्चिम किनारपट्टीवरील एक अति महत्वाचे पर्यटन स्थळ आहे, इथे, बेट, वाळूचेआणिदगडी किनारे आहेत. इथे खडकांवर पोराईटस प्रकारातील प्रजाती अधिकआहेत

असाशोध१९७९ साली कासीम आणि वाफर यांनी लावला. १९८७ साली २९.२२ चौ.किमी क्षेत्रफळ असलेले मालवण समुद्रीअभयारण्यमहाराष्ट्र शासनाने प्रवाळ आणि इथल्या इतर महत्वाच्या प्रजातींच्या संरक्षणासाठी घोषित करण्यात आले. मालवण समुद्रीअभयारण्य हे तालुका मालवण, जिल्हा सिंधुदुर्ग येथील16°15'-16°50' N latitude and 73°27'-73°31' E longitude (Singh, 2003; Barman et. Al., 2007) इतके पसरलेले आहे. मत्स्योद्योगआणि पर्यटन हे मालवण किनारपट्टी वरील प्रमुखउत्पन्नाची साधने आहेत . जरी मालवण किनार्यावरील प्रवाळा चेक्षेत्र हे भारतातील इतर महत्वाच्या प्रवाळ असलेल्या प्रदेशापेक्षा कमी असले तरी कमी खर्ची क प्रवाळ प्रत्यारोपण तंत्रज्ञानाचा वापर करून ह्या जागेतील प्रवाळाचेक्षेत्र वाढवता येईल.

प्रवाळपुनर्वसन

प्रवाळ हे प्राणी असल्यामुळेतेलैंगिक आणि अलैंगिक प्रकाराने पुनरुत्पादन करू शकतात. प्रत्यारोपण तंत्रज्ञानातप्रवलांच्या अलैंगिकपुनुरुत्पादानाचापद्धतीचावापर तुकड्याच्या रूपाने केलाजातो. प्रवाळांचे तुकडे हे चांगल्या प्रतीच्यादाता प्रवालांचा भाग असते, जे योग्य ते वातावरण आणि आधार मिळालातर नवीनवसाहतीची निर्मिती करू शकते. प्रवाळ प्रत्यारोपण हे प्रवाळांचे तुकडे हेकृत्रिमआधाराच्या सहायाने पाण्याखाली सोडल्या जातात. हेतंत्रज्ञान प्रवाळपुंर्वसनाचा एकमहत्वाचा भाग आहे. ह्या तंत्रा मुळेप्रवाळांचीअवनिती थांबते तसेच जिवंतप्रवालांचेक्षेत्र सुद्धा रुंदावते. अनेक प्रयोगांती असे सिद्ध झाले आहे की प्रवाळांचे तुकडे हे प्रवाळ पुनर्वसनाचेएक चांगले अवजार आहे. प्रवाळ प्रत्यारोपाणाची महत्वाची उद्दिष्टे पुढील प्रमाणे आहेत:

- जिवंतप्रवालांचे क्षेत्र रुंदावणे
- जैवविविधता आणिभोगोलिक परिस्थिती

प्रत्यारोपाणाचे तंत्रज्ञान हे किफायतशीरआहेजेणेकरूनकमीत-कमीकिंमतीतजास्तीत जास्त क्षेत्रात प्रवाळांचे पुनर्वसन करतायेईल.

प्रवाळ पुनर्वसनासाठीचेकृत्रिम आधार

योग्य असे कृत्रिम आधार निवडणेहेप्रवाळ पुनर्वसनासाठी फार महत्वाचे असते. सिमेंट-कॉंक्रीट ची बांधणी हि सर्व पर्यायपैकी जास्तयशदाई आहे, कारण ह्या मधील घटक हे नैसर्गिकपरिस्थितीशीअनुरूप असतात. कॉंक्रीट हेखाऱ्या-पाण्यातमजबूत आणि टिकाऊ असते. मन्नारच्या आखात्तातील बऱ्याच प्रयोगान्ती, १ X १ X ०.२५ mआकाराची कॉंक्रीटची बांधणीने चांगले परिणाम दर्शविले, आणि यांचीच पाण्याखालीयोग्यती मांडणी, निवडक जागांवर करण्यात आली. ह्याबांधणीवर सिमेंट-कॉंक्रीट च्याफळ्या(२० सेमी. X१५ सेमी X ५ सेमी) प्रवाळासहितबांधण्यातआले.

प्रवाळ पुनर्वसनासाठी जागेची निवड

प्रवाळ पुनर्वसनाचेजास्तीत-जास्त चांगले निकाल मिळण्यासाठी योग्यअशीजागा निवडणे हे फार महत्वाचे आहे. यासाठी प्रवाळाची वाढ, दाता प्रवाळांची उपलब्धता आणित्यांचे निवडलेल्या जागे पासूनचे अंतर हेमहत्वाचे निकष आहेत.

1. जागेकडेजाण्याची सुलभता
2. पाण्याच्या प्रवाहापासून सुरक्षितता आणि लाटांचेप्रमाण
3. पाण्याची पारदर्शकता
4. ३२ ते ३६ ppt क्षारता
5. २४ ते ३० डिग्री. से. पर्यंतचेतापमान(जास्त वाढी साठी २९ डिग्री. से. तापमान चांगले असते)
6. गोड्यापाण्याच्या प्रवाह (नदी-नाले) यापासून लांब असावे (जरउथळदगडीप्रदेशनसेलआणिगोड्यापाण्याचे१०० मी. लांब असतील तरचालू शकते)
7. किनार्यावर जर वसाहत/ औद्योगिकरण असेल तर प्रदूषणाचे प्रमाण तपासणे आवश्यक आहे.

जरी वरील सर्व निकषावरआधारित जागानिवडलेली असली तरी नैसर्गिक प्रवाळभित्ती जवळीलजागेलाजास्त प्राधान्य दिलेजाणेआवश्यक आहे कारणयेथीलजैविक-भोतिक घटकप्रवाळ वाढीच्या पूरक असतील.

दाता जागा

दाता प्रवाळ हे प्रवाळ प्रत्यारोपणाच्या जागे पासून नजीकच्या(१० समुद्री मैल./ ३०मिनिटे अंतरावरील) नैसर्गिक प्रवाळभित्ती मधील असावीत. हे अंतर प्रवाळावरीलप्रवासाचाताण कमीत-कमी करण्यासाठी आहे. दाता जागा निवडण्यापूर्वी तेथिल आधीवासाचा, प्रवाळाच्या प्रकारचा, उपलब्धतेचाआणि निरोगी असण्याचा अभ्यास करणे आवश्यकआहे. जेथे जास्तीत जास्तप्रवाळ निरोगी आहेत तसेच जिवंतप्रवाळाचे क्षेत्रजास्त आहे ती जागा, दाता जागा म्हणून निवडता येइल.

कृत्रिम आधारांची ने-आण

पाण्याखालील बांधणी स्थिर राहण्यासाठी कृत्रीम आधार सुमारे८०-१०० किग्रा. वजना पर्यंत तयार करण्यात येतात. हे आधार ट्रक/ट्रॅक्टरद्वारे निर्धारित जागेपासुंनच्या नजीकच्या किनाऱ्यावर/ जेट्टीवरनेण्यात येतात. तेथून बोटीने किंवा तराफ्याच्या (एकावेळी ५ टन)सहायाने निर्धारित जागेवर नेतात.

कृत्रिम आधारांना बुडवणे

प्राथमिक चाचणी नंतर निश्चित जागेवर ह्या कृत्रिम आधारांची मांडणी केली जाते. बोटीवरून/ तराफ्यावरुन दोरीच्या सहायाने समुद्रतळाशीसोडतात.पाणबुड्याच्या (स्कूबा डायविंगच्या) मदतीनेसोडलेलेकृत्रीमआधारांची तुट-फुटीसाठी’पडताळणी केली जाते आणि मांडणी मध्ये सवेअसल्यास

थोडेसे बदल केले जातात. १-२ मी. अंतरावर एक अशा प्रकारे यांची समुद्रतळाशीमांडणी करण्यात येते. सातत्याने जाच-पडताळणीसाठी सोपे जावे या साठी सर्वआधारातूनएक रस्सी फिरवली जाते, जिच्या सहायाने आपण लागोपाठचे कृत्रीम आधार लगेचच मागोमाग पाहू शकतो.

प्रवाळ-प्रत्यारोपाणासाठी प्रजातींची निवड

प्रवाळ-प्रत्यारोपाणासाठी प्रजातींची निवड हा सर्वात महत्वाचा घटक आहे. प्रत्यारोपण हे फक्त स्थानिक पर्यावरणातजास्त प्रमाणात आढळणाऱ्या प्रजातींचा वापर करतात, स्थानिकप्रजातीपेक्षा इतर सर्व प्रजातींना स्थानिक परिस्थितीशी जुळवून घेणे कठीण जाते परिणामी त्यांची उत्पादकता घटते. निवडलेल्या प्रजाती ब्लिचिंगआणि रोगप्रतिकारशक्ती जास्त असणारे असावेत. अक्क्रोपोरा, मोन्टीपोरा आणिटर्बिनारिया ह्या लवकर वाढणाऱ्या प्रजाती प्रत्यारोपाणासाठी योग्य आहेत आणि त्याचे परिणाम सुस्पष्ठ आणि प्रवाळाचे क्षेत्र लवकर वाढते..

प्रवाळ तुकडे गोळा करणे

जिथे जास्त प्रमाणात प्रवाळ आढळतात तेथून प्रवाळांचे तुकडेपाण्याखालीच जमवले जातात. साधारणपणेपहाटे-सकाळी प्रवाळाचे तुकडे जमाकेले जातात जेणेकरून त्यांची योग्य ती विल्हेवाट लवकरात लवकर लावता येते.स्कूबा डायविंगच्या मदतीने प्रवाळाचे तुकडे पाण्याखालीभरले जातात. हे तुकडे नेहमी प्रवाहाच्या विरुद्ध दिशेने जमाकेले जातात, कारणजमा करणे पूर्ण झाल्यावर भरलेले बास्केट आणणे सोपे जाते. ३-५% प्रती प्रवाळ वसाहत. प्रवाळ तोडण्यासाठी हाथोडा-छीन्नीचा वापर करतात. नंतर जमा केलेले प्रवाळ तुकडे खाऱ्यापाण्याने भरलेल्यामोठयाटबमध्ये ठेवतात.

प्रवाळ तुकड्यांचीवाहतूक करणे

प्रवाळ वाहतूक करण्यासाठी काळजी तसेच अचूक नियोजन आवश्यकच आहे. प्रवाळ तुकडे मोठ्या टबात ठेवतात.हवा व पाण्याचे अभिसरण करण्यासाठी ऐरेटरचावापरकरतात. सूर्यप्रकाशापासूनवाचवण्यासाठी पांढऱ्या जाड कापडाने टब झाकून ठेवतात आणि लवकरात लवकर निर्धारित स्थळी पोहचवतात. प्रवाळ तुकड्यावरील तणावाचे उत्तम लक्षणे म्हणजे प्रवाळाच्या प्राण्यांनी स्त्रावलेले चिकट लाळी सारखा पदार्थ. हे रोखण्यासाठी टब मधले पाणी वारंवार बदलणे, तसेच पाण्याची क्षारता, तापमान यांचे योग्य नियोजन. पाणी बदलताना वाकड्या नळीचा वापर करून हळुवारपणे टबच्या कडेने पाणी सोडण्यात यावे.

प्रवाळ तुकड्यांची सिमेंटच्याचौकटीवर बांधणे

वातुकीच्या दरम्यानचा वेळ हाप्रवाळांचे तुकडे सिमेंटच्या चौकटीवर(२० से.मी.X ५ से.मी.X १.५ से.मी.) बांधण्यासाठी वापरता येतो. हे करण्यासाठी पाहिलांदा सिमेंटच्या चौकटी खाऱ्यापाण्याने धुवून घेतात. नंतर ८ सें.मी. पेक्षा लहान तुकडे पकडीसारख्या(Bone cutter) अवजारानेकरण्यात येतात. प्रत्येक तुकडा हाचौकाटीवर आडवा (सजीव प्राणी पृष्ठभागावर) ठेऊनबांधतात, जेणेकरून जास्तीत-जास्त भाग हा सिमेंट चौकटीच्या संपर्कात आला पाहिजे. बांधणीहि घट्ट असली पाहिजे आणि त्यासाठी पातळ (२ मी.मी.)

नायलॉन धाग्याचा वापर केला जातो. बांधूनझालेलेतुकडे-सिमेंट चौकटी स्वच्छ खाऱ्या पाण्याच्या टब मध्ये मजबूत/जाड तुकडे खाली आणि नाजूक तूकडे वरती ठेवतात.

सिमेंटस्लॅबवर बांधलेले प्रवाळ तुकडे प्रत्यारोपितकरणे

निर्धारित स्थळावर पोहचल्यानंतर प्रवाळ तुकडे बांधलेलेसिमेंटचेस्लॅब लवकरात लवकर पाण्यामध्येजाळी ट्रे द्वारे स्कूबा पाणबुड्याद्वारेनेतात. तुकडेपाण्यातसोडण्याआधीप्रत्येकतुकड्याच्या बांधणीसाठीतपासणी करतात. जरपाणीजास्त खोलनसेलतरनुसती बुडी मारूनप्रत्यारोपाणाचे कामकरतात. पाण्याखाली टेबलसारख्या सिमेंटच्यासाच्यावर५ से.मी. च्या अंतरावर हेसिमेंटचेस्लॅबमांडलेजातात. नंतरहेस्लॅबनायलॉनच्या दोरीने(२-४ मी.मी.) बांधूनठेवतात, जेणेकरूनतेपाण्याच्याप्रवाहामुळेवाहूनइकडेतिकडेपडतनाहीत.

देखरेखआणिदेखभाल

प्रत्यारोपणामध्ये प्रवाळांचे निरीक्षण प्रत्येक हंगामात केले जाते आणि प्रत्यारोपणानंतर लगेचच पहिल्या महिन्यामध्ये निरीक्षणकरणे आवश्यक असते , कारणप्रवाळांचेतुकडेसिमेंटलानिट चिकटलेलेनसतात. प्रत्यारोपणाच्या शास्त्रीय मूल्यांकनासाठी , प्रत्यारोपणाच्या आजूबाजूच्याजैविक-अजैविकघटकांचीतुलना पाच वर्षांनंतर नैसर्गिक जैविक-अजैविकघटकांशीकरतात. प्रत्यारोपणाच्या प्रवाळांवर देखरेखकरताना, प्रवाळांच्या जीवन-आवश्यक अनेक घटकांपैकी एक म्हणून त्यांच्या आजूबाजूच्यापरिस्थितीचेआणिअधिवासाचे निरीक्षण करणे आवश्यक आहे.
प्रवाळाच्याअस्तित्वावरपरिणाम करणारे काहीमहत्त्वाचे पर्यावरणीय घटक म्हणजे जल तापमान , पाण्याचेप्रवाह,पाण्यातीलगाळाचे प्रमाणआणि भक्षक.

जीवित आणि मृत प्रवाळांची स्थिती

प्र्त्यारोपितप्रवाळांच्याएकूणरंग रुपावरून प्रवाळांचीपरिस्थितीओळखतात -निरोगी प्रवाळ, अंशतः मृत प्रवाळ, आंशिकरित्या जिवंत प्रवाळ, जिवंत प्राण्यांची फारच कमीसंख्या, प्रवाळ जिवंत नाही आणि प्रवाळ नाहीशी झाले. निरोगीप्रवा ळात, प्राण्याचा (पोलीप - प्राण्याचा) रंगहेसामान्यअसतील , कुठच्याही प्रकारची इजा तसेच श्लेष्मल (लाळेसारखा) पापुद्रा नसतो. वाईट (अंशतः मृत प्रवाळ, आंशिकरित्या जिवंत प्रवाळ, मृत प्रवाळ) हेपांढरे-फिकट, श्लेष्मल (लाळेसारखा) पापुद्रयाने झाकलेले, काहीभागस्पंज (प्राणी) किवापाण वनस्प्तीनीआच्छादलेलाअसतो.

प्रवाळांवरील शैवालआणिभक्षकांना काढूनटाकणे

शैवाल कृत्रिमआधारावरपटकनजोमधरतातकारणत्यांचीवाढपटकन होते, त्यामुळे प्रवाळांना योग्यतीतका प्राणवायू नमिळाल्यानेमृतूसंभावतो. त्यामुळेनियमितदेखरेखआणिनिगा - शैवाल काढणे आवश्यकचआहे. प्रवाळ वर्चास्वीत अधिवासातशैवालाच्या ह्या घुसखोरीला प्रवाळ -शैवाल

रुपांतर(coral- algal फेज शिफ्ट) असेम्हणतात, तसेबऱ्याच ठिकाणावरआढळूनदेखिलआलेआहे आणि म्हणूनशैवालांना वारंवारकाढूनटाकणेगरजेचेआहे . प्रवाळ खाणा रेशंख, तरमासा(क्राऊन ऑफथोर्न), प्रवाळभक्षकमासे (पॅरोट फिश) , स्पंज इत्यादीं जरप्रत्यारोपणक्षेत्रातआढळलेतर त्यांच्यवरलाक्षठेवूनत्यांना आटोक्यातठेवणेआवश्यकआहे . जेणेकरूननवीनप्रत्यारोपितकेलेलेप्रवाळतुकडेबाधितहोणारनाहीत.

अडकलेलीमासेमारीचीजाळी काढूनटाकणे

जरएखादेमासेमारीचेजाळेकॉंक्रीटच्याचौकाटीनाअडकलेअसतीलतरतेजाळे तत्काल काढूनटाकलेपाहिजे नाहीतरप्रवाळांवर वाईटपरिणामहोऊशकतो. तसेचबोटीचातळलागणे, ॲन्करटाकणे(फसणे) आदीचीदेखरेखकरणेआवश्यकआहे.

प्रवाळप्रत्यारोपाणाच्या जगण्याचाआणिवाढीचादर

प्रत्यारोपितप्रवाळजगणेहिप्रवाळप्रत्यारोपणाच्याप्रक्रियेतीलसर्वातमहत्वाचीपायरीआहे.जगलेलीप्रवाळ हिइतरनैसर्गिकप्रवाळांप्रमाणे वाढतात.प्रवाळ जातीआणिवाढीचा दर यासहित नियमितपणे नोंदवितात. वाढीचादरहाप्रत्येकतुकड्याचावेगळाअसतोआणितोदरमहिन्यालाबदलूशकतो. वेरनीअर कॅलीपर (विथफ्लेसिबल स्केल) किवासाध्याफ्लेसिबल पट्टीने लांबीआणिरुंदीच्यास्वरुपातमोजतात.महिन्यात, अर्धवर्षात आणिवर्षानंतर एकूण जिवंतप्रवाळांची टक्केवारीच्यारुपातदर्शवितात. हिटक्केवारीआणिनिगडीतप्रत्यारोपणाच्याप्रक्रियेचेमूल्यमापन करण्यासाठी आवश्यकआहे.

ब्लीचिंग आणि रोगाचा प्रसार यासाठीचे निरीक्षण

पाण्याची गुणवत्ता तपासणी

कॉंक्रिटच्या रचना पाण्यात बुडवलेल्यामहिन्यापासून पाण्याच्या नमुन्यांची गुणवत्तात्मकतपासणी केली जाते. हि तपासणी रासायनिक आणि भौतिक घटकांसाठी नियमित करणे आवश्यक असते. कारण हे घटकव सभोवताली घडणारेप्रवाळ परिस्थितीकीतील बदल यामध्ये काही परस्परसंबंध असू शकतात. बऱ्याच प्रवाळ प्रजाती ठराविकक्षारताआणि तापमानातच टिकून राहू शक तात, तसेचपाण्याची पारदर्शकता (आणि पोहोचणारा प्रकाश), साचणारा गाळ , पाण्यातीलऑक्सिजन वायूचे जास्त प्रमाणात बदल हे सर्व प्रत्यारोपित प्रवाळांच्या वाढीत किवा जग विण्यात बाधा उत्पन्न करतात. त्यामुळे, पाण्याचे तापमान, क्षारता, पारदर्शकता, पाण्यातीलऑक्सिजन वायूचे प्रमाण व इतर पोषकतत्वे यांचेनिरीक्षणप्रत्यारोपणाच्या जागेवरनियमितपणे करतात (random sampling). नुकत्याचघडतअसलेले चिंताजनकअसे जगभरातील ब्लेअचींग (प्रवाळ पांढरेपडणे) चे प्रकार आणि त्यांचा पाण्याच्या वाढीव तापमानाशी संबंध तसेच जागतिक तापमान वाढ (ग्लोबल वार्मिंग)

यामुळे प्रवाळ समूहातील तापमाना चीप्रथामिकमाहिती फारच महत्वाची आहे. पाण्याच्या पृष्ठभागापासून ३० से.मी. खोल आणि प्रत्यारोपण रचनाच्या आजूबाजूला (समुद्र-तळाशी) हे तापमानमोजणे आवश्यक असते.

पाण्यातीलऑक्सिजनवायूचे प्रमाण हे प्रत्यारोपित प्रवाळाच्याआणि इतर सजीवांच्या जगण्यासाठीफारच महत्वाचे आहे . हे प्रमाणक मी झाल्यास वाढीवबॅक्टेरीआ हेप्रमाण आहे. क्षारतेतीलबदल हे गो ड्यापाण्याचा आवक , वाढीव तापमान किवा जास्त खारट पाण्याच्या स्त्रोत(फॅक्टरीतून सोडलेले पाणी) ह्या मुळे होतो. क्षारता"रीफ्राक्टोमिटर" च्या सहहायाने मोजतात. पाण्याचा सामू तसा साधारणता: खूप काळ बदलत नाही , परंतु तो अचान कपणेबदलला तर काहीतरी नवीन प्रकारचेप्रदूषणअसण्याचासंभाव असतो. सामू हा सामू कागदाने (पी.एच. पेपर) किवा pH मीटर ने मोजतात. पाण्याची पारदर्शकता आणि त्यामधील न- विरघळेले नोंद आणि प्रमाण निर्धारित पद्धतीनी मोजतात.

पाण्यात उपलब्धप्रकाश हा,मुक्ततसेचबांधील अश्या शैवालाच्या प्रकाश-संश्लेषण क्रियेसाठीमहत्वाचा आहे. त्यामुळे प्रवाळ आणि इतर सजीवांची वा ढीवर परिणाम होऊशकतो . **सेच्ची डिस्क** च्या सहाय्याने पाण्याचीउभी पारदर्शकता मोजता येते . प्रवाळांना आणिइतर सजीवांना कॅल्शिअम, नायट्रेट, नायट्राइट, क्लोराइडस इ. पोषकतत्वेकमी-अधिक प्रमाणात आवश्यक आहेत. ह्यांच्यातील बदल हा मोठे शैवाल आणि बॅक्टेरीआ यांची संख्या बदलतो. त्यामुळे ह्या पोषकतत्वाची नोंद आणि प्रमाण निर्धारित पद्धतीनी मोजतात.

तळातीलसमुदाय वपरिस्थितिकी

प्रवाळ पुनर्वसनाचे यश हेतेथीलतळातील परिस्थितिकीतील बदलाच्याद्वारे दर्शविता येतात. यामध्ये सर्व तळातील चिकटलेले (स्थिर)सजीवगणले जातात.नियमित कालांनतराने समुद्रतळातील समुदाय परिस्थितिकीच्या रचनाचे मुल्यांकन करून, त्याआधारे थेट प्रवाळआच्छादन वाढत आहे की नाही जाणूनघेता ये ते.प्रवाळआच्छादन वाढ णे हे प्रत्यारो पणाचे यश दाखवतात. तसेच समुद्रातालातीलपरिस्थितिकी चांगल्या अवस्थेत आहे की नाही हे सुद्धा वरील अभ्यासाने जाणून घेता येते.ह्या सर्वासाठी लाईन इंटर्सेप्ट ट्रान्सेक्ट पद्धतीचा वापर करतात.

माश्यांचीघनता

मासेअधिवासाच्याविविध पैलुना प्रतिसादत्यांच्याघनतेच्याआणिप्रजातीतील विविधतेच्या आधारे देतात. हि विविधता आणि घनता अधिवासातीलरचनात्मक गुंतागुंतता यावरप्रामुख्यानेअवलंबूनअसते. जेव्हा प्रत्यारोपीत प्रवाळ वाढतात आणि अधिवासाची गुंता-गुंत वाढवतात तेव्हा मासे विपुल प्रमाणात वाढतात आणि त्यामुळे प्रवाळ पुनर्वसना चे यश दर्शवितात.माशांच्या समुदायांचे मूल्यांकन करण्यासाठी बेल्ट ट्रान्सेक्ट पद्धतीचा वापर करून पाण्याच्याखाली त्यांची गणना केली जाते.

समुद्रतळावरील जीव-जंतू

समुद्रतळाशीसोडण्यात आलेल्या रचनावरीलप्रजातींचे आच्छादन आणि त्यांचीघटना हि नमुन्याच्याअभ्यासावरआधारित आहे. समुद्रतळावरील जीव-जंतू चेनमुनेचौरसपद्धतीने (quadrat method) गोळा करून, त्यांचाअभ्यास केला जातो वेगवेगळ्या प्रकारच्या प्रजाती, किती व कुठे आढळतात याचा अभ्यास करतात.

प्रवाळ प्रजननाची देख-रेख

प्रत्यारोपितप्रवाळ तुकड्यांच्यापुनुरूजीवनाच्या तुलनेत वाढ व जगण्याचा दर हे अधिक महत्वाचेघटक आहेत, परंतु जर प्रत्यारोपित प्रवाळ प्रजननकरू शकली, तर एकूण प्रवाळ स्थानाच्या पुनर्वसनासाठी अधिक योगदान मिळेल. जस जसे प्रत्यारोपित प्रवाळांचीवाढ होईल तस-तसे त्यांचेनिरीक्षण हेस्थानिकप्रवाळांच्या नैसर्गिक प्रजनन कालावधीच्या समीप करणे आवश्यक आहे. वर्षागणिक किंवा स्थानानुसारप्रजनन कालावधी वेगवेगळा असतो, पण हे प्राणी उन्हाळ्याच्या सुरवातीच्यापौर्णिमेलाअंडीपाण्यात सोडतात (spawning). त्यामुळे प्रवाळांच्याबहुभूजांचे सततचे निरीक्षण हे अति आवश्यक आहे.

प्रवाळांचीनैसर्गिक वाढआणिसंगोपन

प्रवळांचे प्रजनन, बीज उत्पादन आणि त्यांचे प्रत्यारोपित रचनावर स्थाईक होणे हे सर्व नियमितपणे तपासणे आवश्यक आहे. १ X १ मी. चौरसाच्या सहाय्याने प्रवाळांच्या या रचनांवर स्थाईक होण्याच्यापध्दती आणि प्रकार लक्षात घेता येतो.

संदर्भ

11. Barman, R.P., Mukherjee, P. and Das, A. 2007. On a collection of fishes from the Malvan Marine Sanctuary, Malvan, Maharashtra, India, 2007, *Records of zoological survey of India*, 107(Part-1): 71-87.
12. Cesar, H., Burke, L. and Pet-Soede, L. 2003. The economics of worldwide coral reef degradation. Cesar Environmental Economics Consulting and WWF-Netherlands, Arnhem and Zeist, The Netherlands. pp23.
13. Edward, J.K.P., Patterson, J. and Mathews, G. 2006. Restoration techniques for conservation and management of coral reefs. In: Training manual of the national training workshop on Marine and Coastal Biodiversity Assessment for Conservation and Sustainable Utilization: 280-286.
14. Edward, J.K.P., Patterson, J., Mathews, G. and Wilhelmsson, D. 2005. Awareness raising and feasibility of reef restoration, through coral transplantation in Tuticorin, Gulf of Mannar, India. Coral Reef Degradation in the Indian Ocean (CORDIO) – Status Report 2005: 243-251.
15. Hughes, L., Steffen, W., Rice, M. 2016. Australia's coral reefs under threat from climate change, Climate Council of Australia Ltd., pp 22.
16. Kalyan De, Sautya, S., Mote, S., Tsering, L., Patil, V., Nagesh, R. and Ingole, B. 2015. Is climate change triggering coral bleaching in tropical reef? *Current Science*, 2015, 109(8): 1379-1380.
17. Lindahl, U. 2003. Coral reef rehabilitation through transplantation of staghorn corals: effects of artificial stabilization and mechanical damages. *Coral Reefs*, 22: 217-223.
18. Moberg, F., and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics*, 29(2): 215-233.
19. Pandolfi, J. M., Bradbury, R. H., Sala, E., Hughes, T. P., Bjorndal, K. A., Cooke, R. G., McArdle, D., McClenachan, L., Newman, M. J. H., Paredes, G., Warner, R. R. and Jackson, J. B. C. 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science*, 301: 955-958.
20. Singh, H.S. 2003. Marine protected areas in India, *Indian J. Mar. Sci.*, 32(3): 226-233.