Chapter-5

Results and discussion

Results and Discussion

In order to bring forth the carbon storage potential of the coral reefs of Gujarat, a total of 6 coral reef sites were identified for sample collection. Prior to sample collection, the sites were surveyed and benthic profiles were generated for suitable location in the 5X5m quadrates which was followed by core drilling operation. A total of 13 cores were procured from 6 different sites of the Gulf of Kachchh, 2 from each site except Ajad (3 cores-as one of the cores was procured less than 50% = 33cm). Hence, the results include following points:

(a) Benthic coverage around the sampling points

(b) Details of the collected samples-*dead coral cores*-which is produced after morphological studies of the cores

(c) Age of the samples collected from various levels of the core

(d) Accretion rate and carbon storage potential of the coral reefs

The sampling sites were selected to give the optimum data for the till date stored carbon as well as the presence of live coral which ensures the addition of future carbon in the form of calcium carbonate unless they become victim of natural calamities. In general it was observed that all the cores have dark colours at upper part that gradually decreases in lighter shade further below. This indicates the sedimentation penetration inside the porous massive coral framework as well as stable condition of the substrate for a long time. Additionally,
The site wise details of the sampling point and core morphology is given below (Figure 5.1):

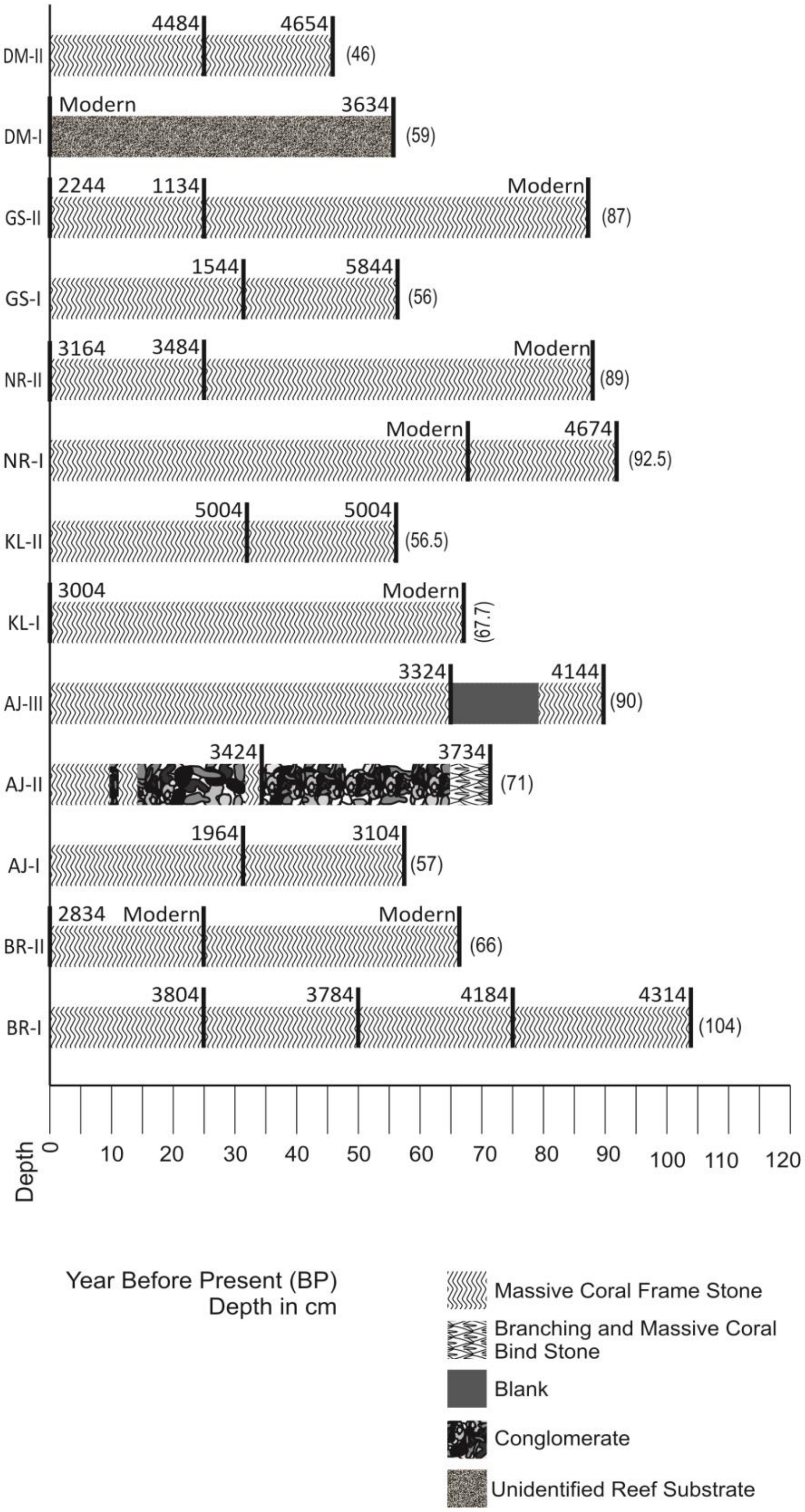


Figure 5.1 Ages of different Cores along with the relevant depth

5.1 Core morphology and Sampling point details

BORIA (BR)

Description of the sampling point BR-1

The sampling point BR-1 was located at the northern most narrow reef platform (Figure 5.2). The sampling point falls in the reef flat of the Boria reef. The reef rock selected for drilling was large having 1.5 to 2 m diameter and more than 1.5 meter depth with uneven topography. The rock was moderately perforated by bivalves. The upper surface was covered by thin layer of sedimentation.

Benthic profile of the sampling point BR-1

The quadrate data showed highest presence of rubble (50%) at both the sites followed by rock (25%) and algae (15%) (Figure 5.3). The % cover and diversity of live coral are higher at both the sites of Boria in compare to Ajad. The live coral cover was 4% which included 1-2 % of soft corals i.e., *Sinularia spp*. other live corals included *Porites lutea*, *Goniopora minor*, *Goniopora nigra*, *Favites bestae*, *Cyphastrea serailia*, *Turbinaria peltata.*

Figure: 5.2 Sampling points on Boria reef

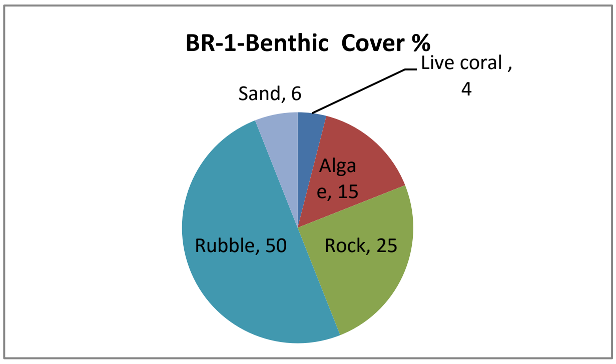
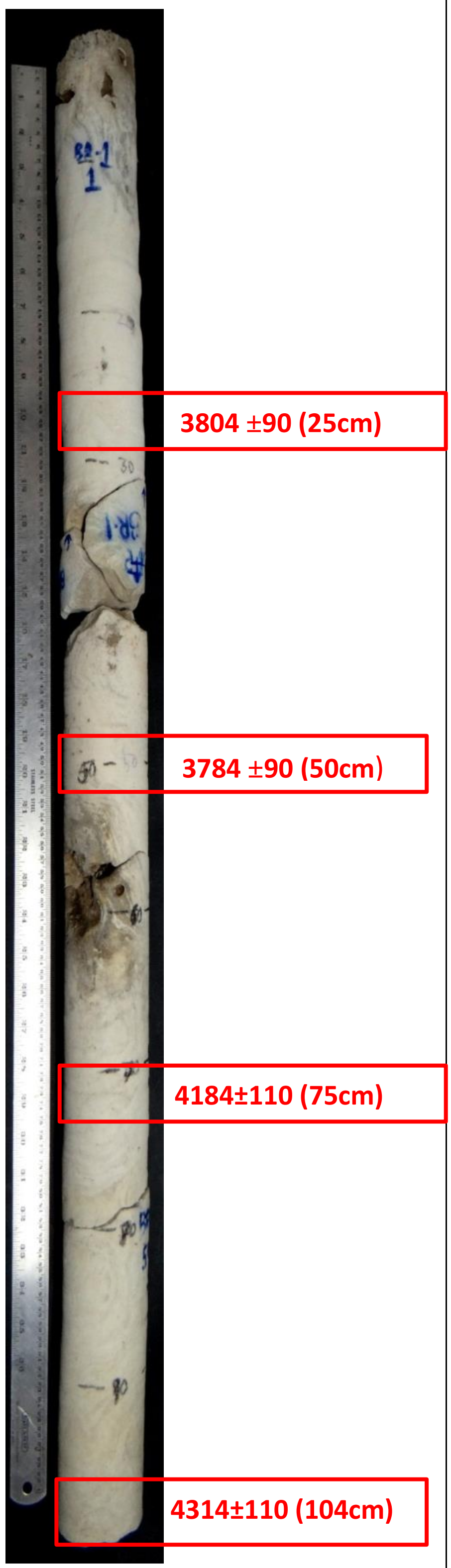


Figure: 5.3 % Coverage of benthic components at Boria reef

Table 5.1 Core morphology-BR-1

Core Code &	BR-1
GPS	N22° 23’ 34.1” E 69° 15’16.3”
Location	Boria
Core length	100 cm
Drilling depth	104 cm
Core recovery	96%
Breakage (cm from top)	4 Breakages at 32, 40, 46, 89cm
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy
Growth axis	More or less vertical
Colouration	Earthy grey at top 15 cm and bottom 20 cm, gradually decreasing in creamy white at middle, Dark patch between 50-70 cm
Perforation	Bivalve bores at top and between 50-60 cm
Top-bottom	Green algae at top
Source	Reef rock
Reef Zone	Reef flat

BR:1



Description of the sampling point BR-2:

The sampling point BR-2 was also located still northward of the BR-1, at the northern most narrow reef platform. The sampling point falls near the edge of the Boria reef in the zone of high wave energy. The reef rock selected for drilling was smaller compare to previous one. The rock was heavily perforated by bivalves was covered by thick layer of sedimentation and also showed sediment infestation.

Benthic profile of the sampling point BR-2

The quadrate data showed highest presence of rubble (40%) at both the sites followed by rock (30%) and algae (25%) (Figure5.4). The % cover and diversity of live coral (4%) are higher at both the sites of Boria in compare to Ajad. The live corals included *Montipora foliosa*, *Porites lutea*, *Favites bestae*, *Cyphastrea serailia*, *Turbinaria peltata.*

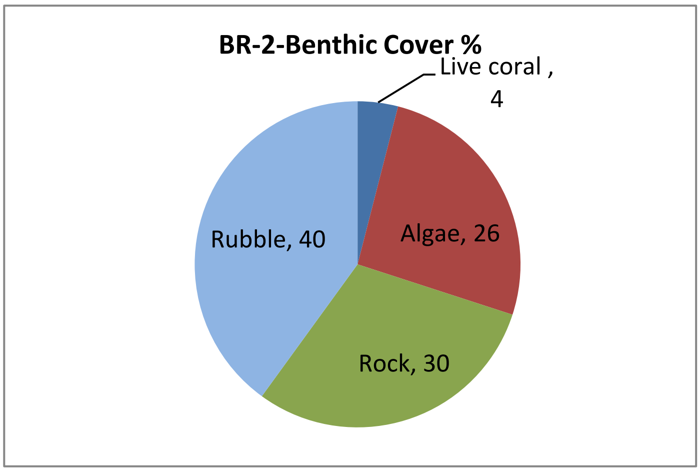


Figure: 5.4 % Coverage of benthic components at Boria reef

Table 5.2 Core morphology-BR-2

Core Code & GPS	BR:2; N 22° 23’37.3” E 69° 15’14”
Location	Boria
Core length	54 cm
Drilling depth	66 cm
Core recovery	82%
Breakage (cm from top)	3 breakages at 29, 36.5, 43cm
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy with thin light and very dark bands
Growth axis	More or less vertical
Colouration	Many dark patches as well as dark colouration visible due to longitudinally broken pieces
Perforation	Continuous bivalve perforation and micro pores
Top-bottom	Green algae at top
Source	Reef rock
Reef Zone	Reef edge
Age	Modern

BR:2

AJAD (AJ)

Descriptions of the sampling point AJ-1

The sampling point AJ-1 was selected on the western most reef of the Ajad Island (Figure5.5). The sampling point falls in the inner reef flat. The reef had approximately 0.5 to 1m depth. The reef zone was of moderate energy compare to rest of the samples collected from Ajad.

Benthic profile of the sampling point AJ-1

The quadrate data mainly showed the presence of rubble as major benthic component, *i.e.*, 70%. The rock followed the rubble coverage i.e., 20% (Figure5.6). The reef area showed 10 % mud over rock and rubble. The sedimentation was 1-2 cm at different sites. The rubble included broken pieces of *Porites lichen*, *Favia spp*, other corals and encrusting corals. The live coral species include *Porites lutea*, *Goniopora minor*, *Goniopora nigra*, *Favia favus.*

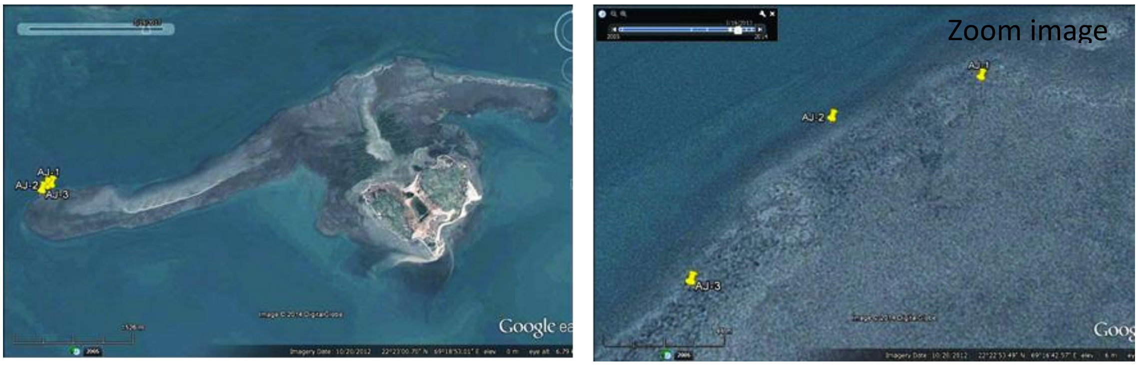


Figure 5.5 Sampling points on Ajad Island

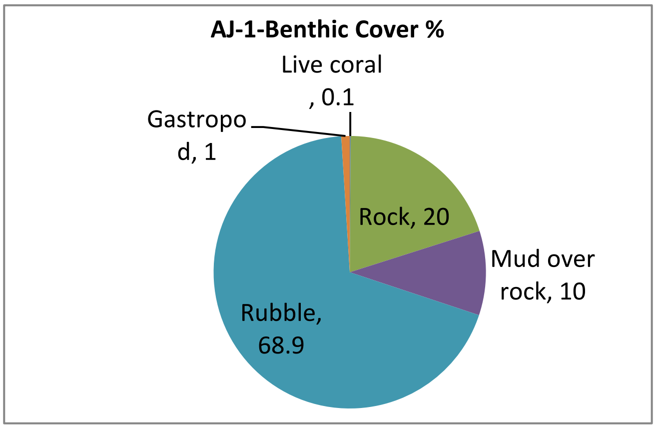
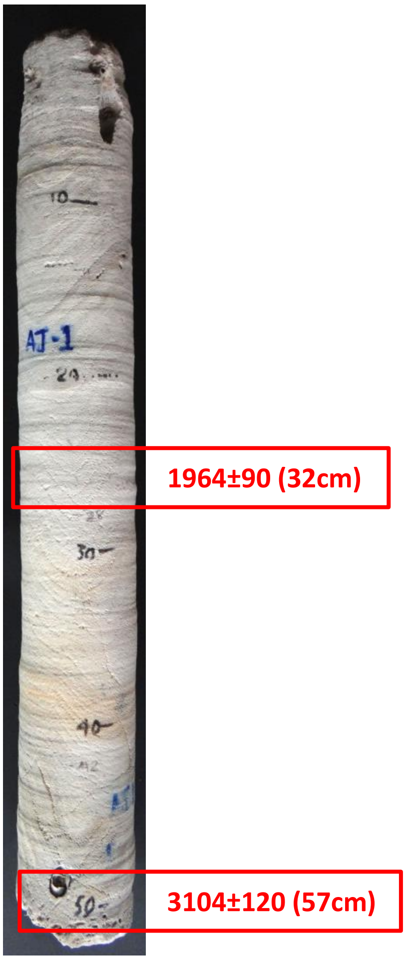


Figure 5.6 % Coverage of benthic components at Ajad Island

Table 5.3 Core morphology-AJ-1

Core Code & GPS	**AJ:1; N22° 22’55’ E69°16’43.9”**
Location	Ajad
Core length	53 cm
Drilling depth	57 cm
Core recovery	93 %
Breakage (cm from top)	No breakage single piece
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy
Growth axis	More or less vertical
Colouration	Earthy grey, Gradually decreasing in creamy white, Bottom very dark
Perforation	Bore holes of bivalve (17-20 cm)
Top-bottom	Green algae at top and bottom showed bore holes
Source	Reef rock
Reef Zone	Reef flat

AJ:1



Descriptions of the sampling point AJ-2:

The sampling point AJ-2 was selected on the western most reef of the Ajad Island more towards the seaward side compare to AJ-1. The sampling point falls between outer reef flat and the reef crest. The reef zone had high wave energy and sedimentation rate compare to rest of the samples collected from Ajad.

Benthic profile of the sampling point AJ-2:

The quadrate data mainly showed the presence of rubble as benthic cover, *i.e.*, 45 % at different sites. The rock followed the rubble coverage *i.e.*, 30 % (Figure 5.7). The reef area showed 23 % mud over rock and rubble. The rubble included broken pieces of *Acropora humilis*, *Porites lichen* and encrusting corals. The live coral species include *Porites lutea*, *Goniopora minor*, *Goniopora nigra.*

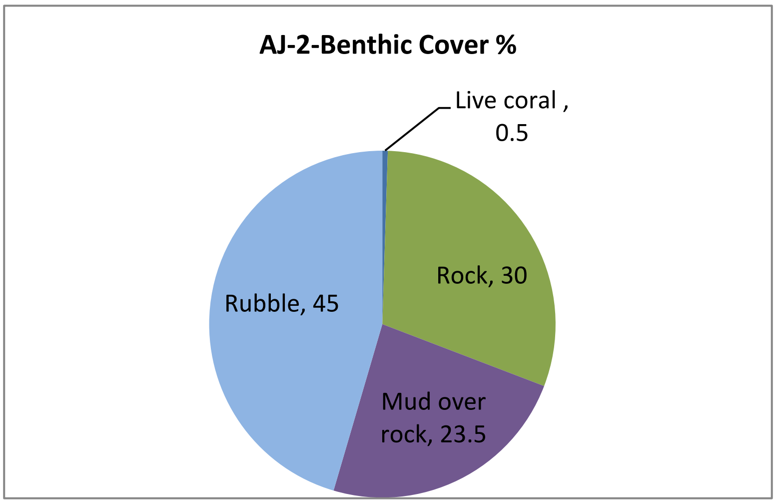
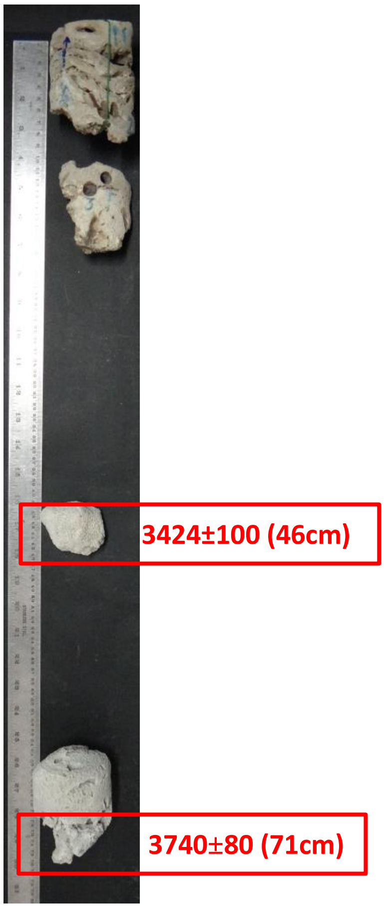


Figure: 5.7 % Coverage of benthic components at Ajad Island

Table 5.4 Core morphology-AJ-2

Core Code & GPS	AJ:2; N22° 22’54.3” E69°16’ 41.6”
Location	Ajad
Core length	33 cm
Drilling depth	71 cm
Core recovery	46%
Breakage (cm from top)	No breakage but 4 pieces separated due to sedimentation
Facies type	Bind stone of Massive, encrusting and branching Corals and frame stone of massive corals as well as cementing calcareous algae and molluscs
Growth band pattern	Wavy in some of the pieces
Growth axis	Vertical in upper pieces and lower but not clear in middle one.
Colouration	Earthy grey, Gradually decreasing in creamy white, Bottom very dark
Perforation	Bore holes of reef bivalve
Top-bottom	Green algae at top and bottom showed bore holes
Source	Reef rock
Reef Zone	Reef crest (reef flat)

AJ:2



Descriptions of the sampling point AJ-3

The sampling point AJ-1 was selected on the western most reef of the Ajad Island. The sampling point falls in the outer reef flat. The reef had approximately 1m depth with large uneven rock topography. The reef zone had high wave energy and the selected rock had a sloppy topography.

Benthic profile of the sampling point AJ-3

The quadrate data mainly showed the presence of rubble as benthic cover, *i.e.*, 60%. The rock followed the rubble coverage i.e., 20% (Figure 5.8). The reef area showed 20 % mud over rock and rubble. The sedimentation was 1-2 cm at different sites. The rubble included broken pieces of *Porites lichen*, *Favia spp*, other corals and encrusting corals.

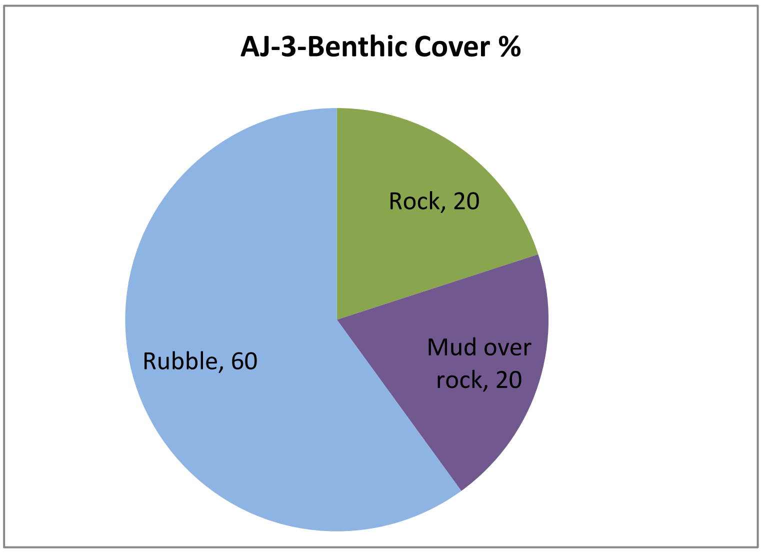
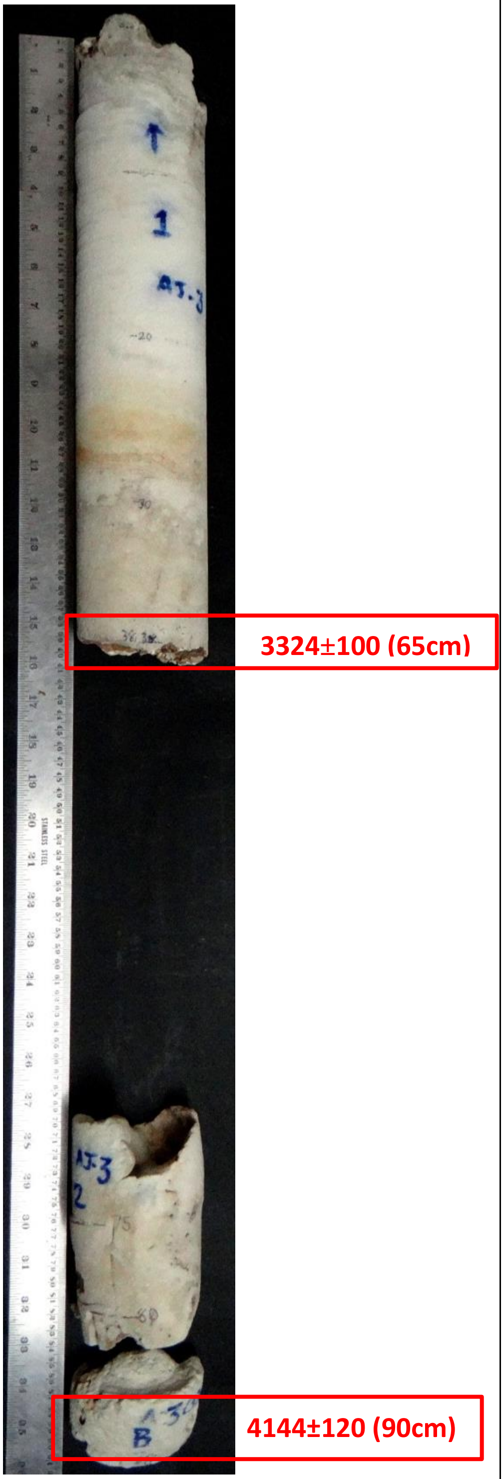


Figure: 5.8 % Coverage of benthic components at Ajad Island

Table 5.5 Core morphology-AJ-3

Core Code & GPS	**AJ:3;** N22° 22’ 52” E69°16’ 39.9”
Location	Ajad
Core length	60 cm
Drilling depth	90 cm
Core recovery	64 %
Breakage (cm from top)	No breakage but hollow space
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy in first piece UI in rest pieces
Growth axis	More or less vertical
Colouration	Whole core with light and dark bands; Last piece was covered with some cementing material and blotted with dark brown-black stain
Perforation	Bore holes of bivalve on top and bottom circumference of first two pieces;50-60 micro pores of less than 1mm diameter on top circumference of 1^{st} piece
Top-bottom	Green algae at top
Source	Reef rock
Reef Zone	Reef flat

AJ:3



KALUBHAR (KL)

Description of the sampling point of KL-1

The sampling point of KL-1 was selected on a reef rock having very rough and sticky surface and covered with brown and sparsely distributed green algae (Figure 5.9). The rock had semi-circular shape with approximately (due to unevenness of the shape) 1meter diameter and 1 meter height.

Biodiversity: The rock was perforated with reef borers and the biodiversity included tubeworms and calcifiers like bivalves and barnacles.

Benthic profile of the sampling point

A 5x5 meter quadrate was laid around the sampling point, which showed near about 50% benthic cover is barren reef rock near the drilling point (Figure 5.10). Considerable amount of large boulders was observed near the sampling point. About 24% of the rock was covered by mud. The rest is algae, live coral and silt.

Figure 5.9 Sampling points on Kalubhar Island

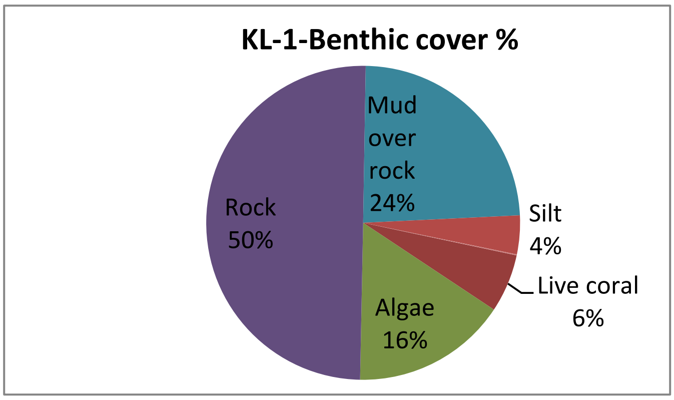


Figure 5.10 % Coverage of benthic components at Kalubhar Island

Table 5.6 Core morphology-KL-1

Core Code & GPS	**KL-1;** N22° 27' 49.8" E69° 39' 29.6" (Kalubhar)
Core length	67.7 cm
Breakage (cm from top)	(5)17, 39, 56, 63.5, 66.5
Facies type	Massive/encrusting Coral Frame stone
Growth band pattern	Wavy
Growth axis	Vertical (0°)
Colouration	Top 3.5 cm earthy grey, rest cream with brown patches
Perforation	Minute perforations at top
Top-bottom	Dark top with algae and perforation, Corallites of 0.1 cm
Distance from LTL	120m
Source	Reef rock
Reef zone	Reef edge

KL-1

Description of the sampling point of KL-2:

The sampling point of KL-2 was selected on a reef rock with very uneven shape covered with brown algae and no perforations (Figure 5.11). The top surface was flat with 1.3 meter length and without curvatures and roughness. The reef rock was covered with brown algae and barnacles.

Benthic profile of the sampling point:

A 5x5 meter quadrate was laid around the sampling point, which showed near about 60% benthic cover is barren reef rock near the drilling point. Following to it is algae, sand, mud live coral and rubble.

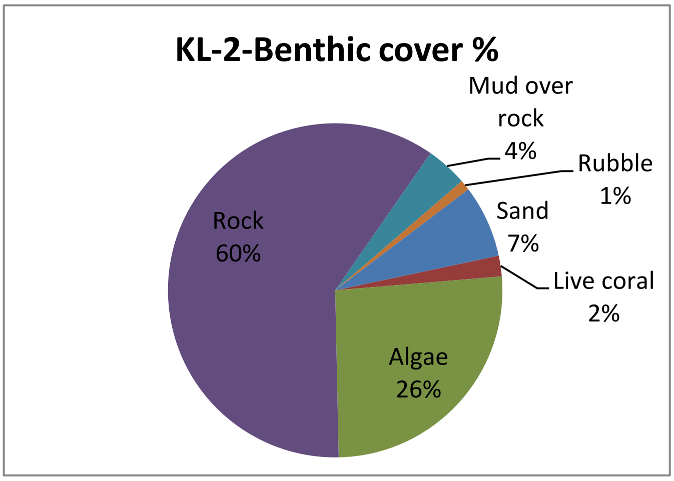
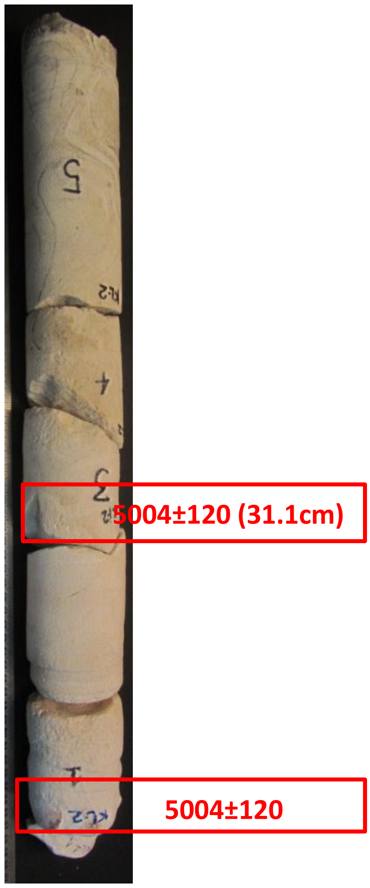


Figure 5.11: % Coverage of benthic components at Kalubhar Island

Table 5.7 Core morphology-KL-2

Core Code & GPS	**KL-2;** N22° 27’ 52.8” E69° 39’11.2 ” (Kalubhar)
Core length	56.5 cm
Breakage (cm from top)	(4)19.5, 28, 37.5, 47.7
Facies type	Massive/encrusting Coral Frame stone
Growth band pattern	Wavy
Growth axis	UI
Colouration	Earthy grey, gradually decreasing up to 35 cm, Dark patches at 0-8.5 & 17-22cm, rest cream
Perforation	Minute perforations at top
Top-bottom	Uneven rough surface with minute perforations, Corallites of 0.1 cm
Distance from LTL	55m
Source	Reef rock
Reef zone	Reef edge

KL-2



NARARA (NR)

Description of the sampling point of NR-1:

The sampling point of NR-1 was selected on a reef rock having roughly rectangular shape and broad near bottom (Figure 5.12). The length of the top surface was less than 1 meter and height 1.3 meter covered with brown algae. Drilling was performed on the dead area of the rock without disturbing any biodiversity.

Coral species found on the rock surface *Goniastrea*, *Cyphastrea*, *Goniopora and Favites*

Other fauna: Barnacles, Sea anemone

Benthic profile of the sampling point:

A 5x5 meter quadrate was laid around the sampling point, which showed near about 50% benthic cover is barren reef rock near the drilling point following to it is algae, Live coral, sand and sponges (Figure 5.13).

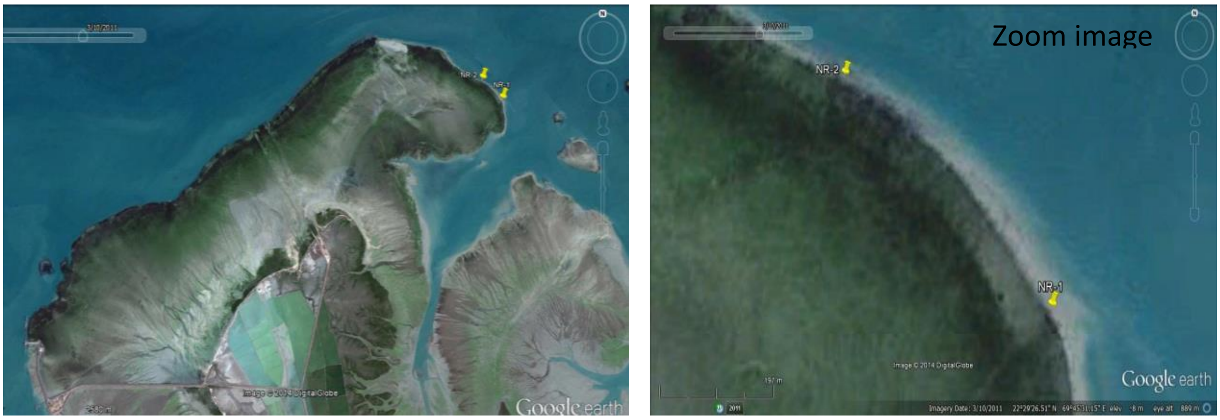


Figure 5.12 Sampling points on Narara Island

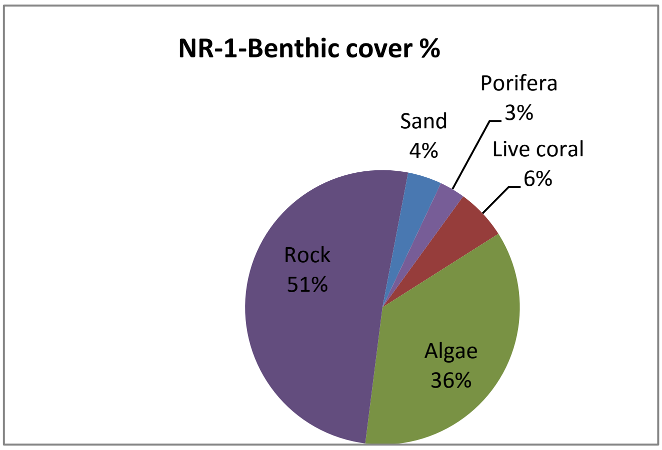
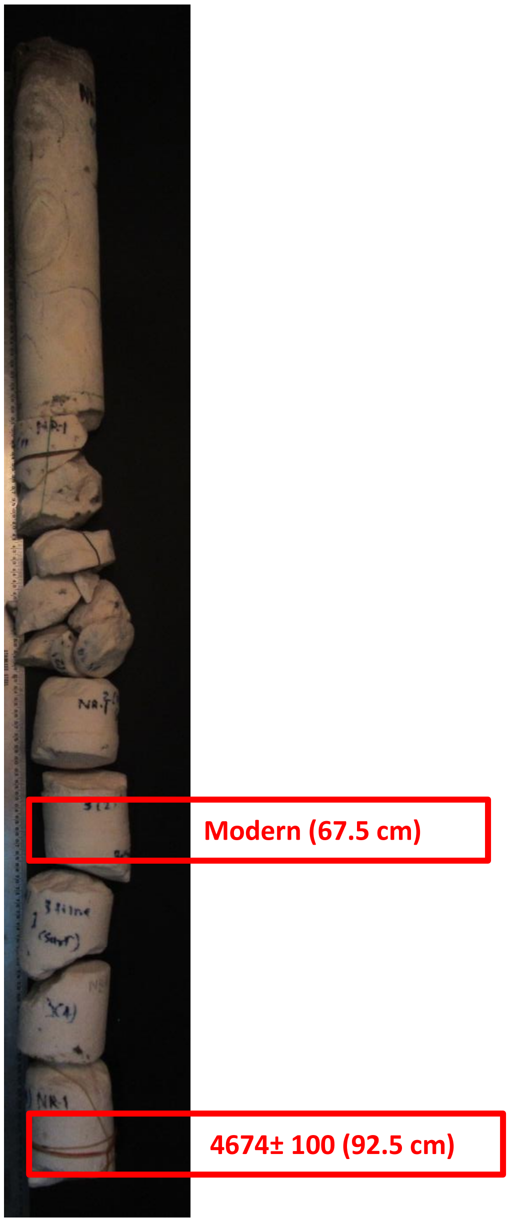


Figure 5.13: % Coverage of benthic components at Narara

Table 5.8 Core morphology-NR-1

Core Code & GPS	**NR-1;** N22° 29' 21.5 " E69° 45' 38.5 " (Narara)
Core length	92.5 cm
Breakage (cm from top)	(7):30, 36, 40.5-49((broken pieces), 55, 63.5, 73.5
Facies type	Massive Coral Frame stone
Growth band pattern	Non uniformous / Random Growth bands
Growth axis	Vertical at some places, patches showing T.S. of the colony
Colouration	Earthy grey, up to 7cream and dark cream patches from 7-19cm, rest cream
Perforation	Single at top: 3.5 cm oblong
Top-bottom	Barnacle shell at top
Distance from LTL	120m
Source	Reef rock
Reef zone	Reef edge

<u>**NR-1**</u>



Description of the sampling point of NR-2

The sampling point of NR-2 was selected on a reef rock having uneven shape 1 meter height and flat surface with a gentle slope towards the seaward side. The rock was having 1-2 horizontal depressions near the bottom and the middle point.

Biodiversity: Calcareous algae, zooanthus, egg, bivalve

Benthic profile of the sampling point

A 5x5 meter quadrate was laid around the sampling point, which showed near about 50% benthic cover is barren reef rock near the drilling point which is followed by algae and sand (Figure 5.14). The rock was in form of large boulders some of which were completely covered with zooanthus. The coral cover is higher at NR-2 point in compare to the first drilling point; the coral species included *Goniopora, Favites, Favia and Porites.*

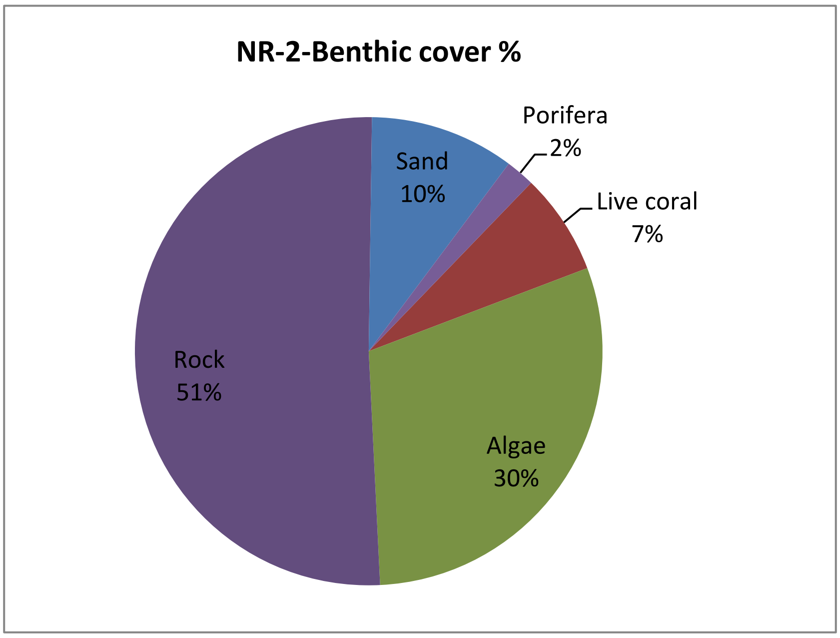
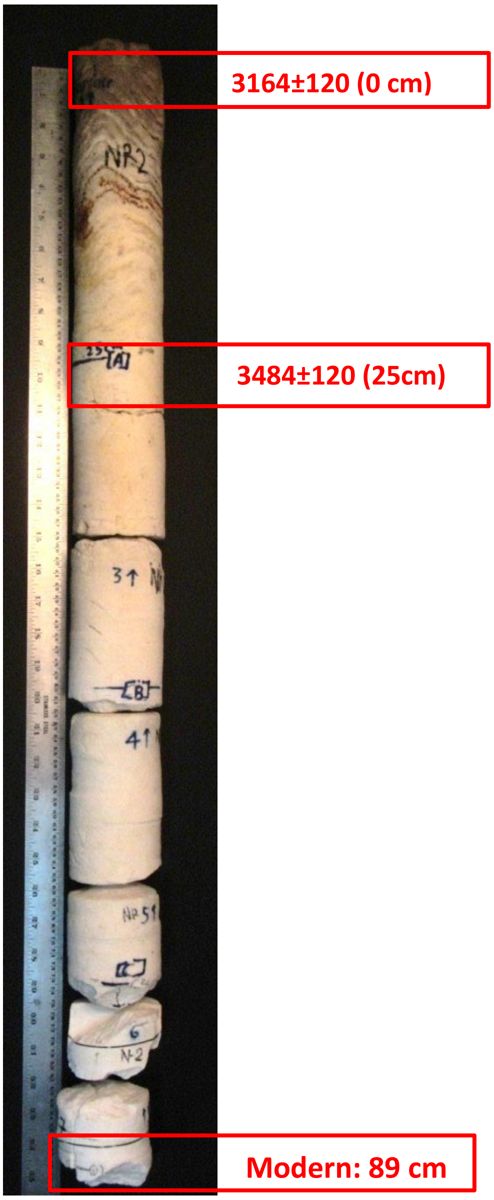


Figure 5.14 % Coverage of benthic components at Narara

Table 5.9 Core morphology-NR-2

Core Code & GPS	**NR-2;** N22° 29’ 33.6” E69° 45 ’ 24.9” (Narara)
Core length	89 cm
Breakage (cm from top)	(6) 29, 39, 52, 65, 73.5, 80.5
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy
Growth axis	Vertical (0°)
Colouration	Earthy grey, gradually decreasing up to 27 cm (dark and light stripes along with G.B.), rest cream
Perforation	Single oblong , round borehole
Top-bottom	Uneven rough surface with minute perforations and algal coverage, Bottom longitudinally broken and very uneven
Distance from LTL	60m
Source	Reef rock
Reef zone	Reef edge

NR-2



GOOSE (GS)

Description of the sampling point of GS-1

The sampling point of GS-1was selected on a reef rock having slope opposite to seaward side (Figure 5.15). The rock was roughly circular in shape with 1 meter height and uneven surface covered with brown algae.

Biodiversity: Barnacles and gastropods

Benthic profile of the sampling point

A 5x5 meter quadrate was laid around the sampling point, which showed maximum benthic cover is barren reef rock near the drilling point. Algae, sand and rubble followed respectively(Figure 5.16). The gastropods and Bivalves are the main calcium carbonate contributor after corals.

Figure 5.15 Sampling points on Goose

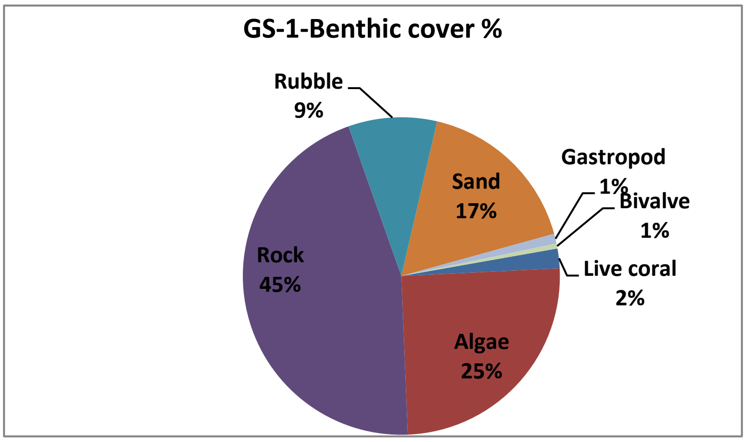
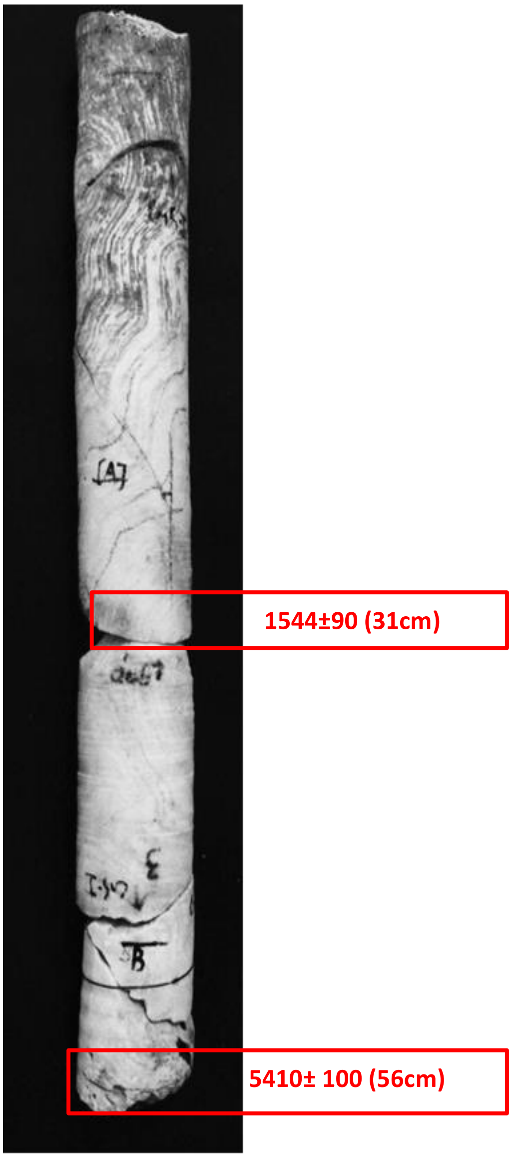


Figure 5.16 Coverage of benthic components at Goose reef

Table 5.10 Core morphology-GS-1

Core Code & GPS	**GS-1 ;** N22° 29’ 26.9” E69° 47’10.6” (Goose)	**GS-1** 
Core length	56 cm	
Breakage (cm from top)	(3): 7, 34, 47.5	
Facies type	Massive Coral Frame stone	
Growth band pattern	Wavy	
Growth axis	Tilt (45°)	
Colouration	Earthy grey, Gradually decreasing in creamy white, Bottom very dark	
Perforation	More than 15 round to oblong bore-holes near bottom	
Top-bottom	Top covered with cream calcareous sheath, Corallites of 0.1 cm	
Distance from LTL	90m	
Source	Reef rock	
Reef Zone	Reef edge	

Description of the sampling point of GS-2

The sampling point of GS-2 was selected on a reef rock was oblong in shape with 1.7 meter length and 1 meter height, having slope towards the rock edges. The rock was covered with brown and calcareous (pink) algae with almost even surface. Drilling was performed on the dead area of the rock without disturbing any biodiversity.

Biodiversity: Barnacles, worms, bivalves and crabs

Benthic profile of the sampling point

A 5x5 meter quadrate was laid around the sampling point, which showed near about 40% benthic cover is barren reef rock near the drilling point following to it is green algae(Figure 5.17). Considerable amount of large boulders was observed near the sampling point. The live coral cover is higher at this site compare to the GS-1 including the coral species *i.e. Goniopora, Cyphastrea, Goniastrea, Favia and Porites.*

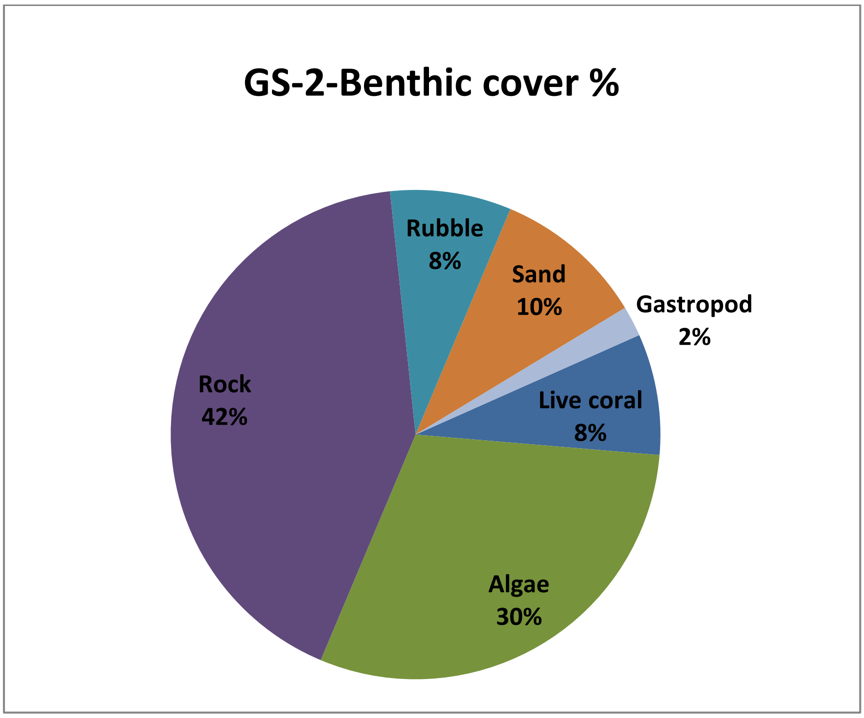


Figure 5.17: Coverage of benthic components at Goose reef

Table 5.11 Core morphology-GS-2

Core Code & GPS	**GS-2;** N22° 29' 40.5" E69° 47' 23.8" (Goose)
Core length	87 cm
Breakage (cm from top)	(3): 51.5, 61.5, 73.3
Facies type	Massive Coral Frame stone
Growth band pattern	Wavy
Growth axis	Vertical (0°)
Colouration	Earthy grey , gradually decreasing up to 19 cm, rest cream
Perforation	2: at 9.7 &12.1 cm from Top, Resembling half cut barnacle
Top-bottom	4-5 barnacle shell at top , Corallites of 0.1 cm at both the ends
Distance from LTL	50m
Source	Reef rock
Reef zone	Reef edge (Boulder zone)

GS-2

DEDEKA-MUNDEKA (DM)

Description of the sampling point of DM-1:

The sampling point of Dedeka-Mundeka DM-1 falls in a hard ground near the wave cut edge of the reef, after that there was a steep slope towards the seaward side with sand bottom(Figure 5.18). The large hard ground had quite uneven surface covered with pink calcareous algae. The edge being washed by waves had bright live corals along with large colonies inside the scattered deep rock pools.

Biodiversity: Barnacles, gastropods and calcareous algae

Benthic profile of the sampling point:

A 5x5 meter quadrate was laid around the sampling point, which showed maximum benthic cover is reef rock near the drilling point contributing about 70% to the benthic coverage of the quadrate. Algae, sand, live coral and rubble followed respectively. The gastropods and Bivalves are the main calcium carbonate contributor after corals(Figure 5.19).

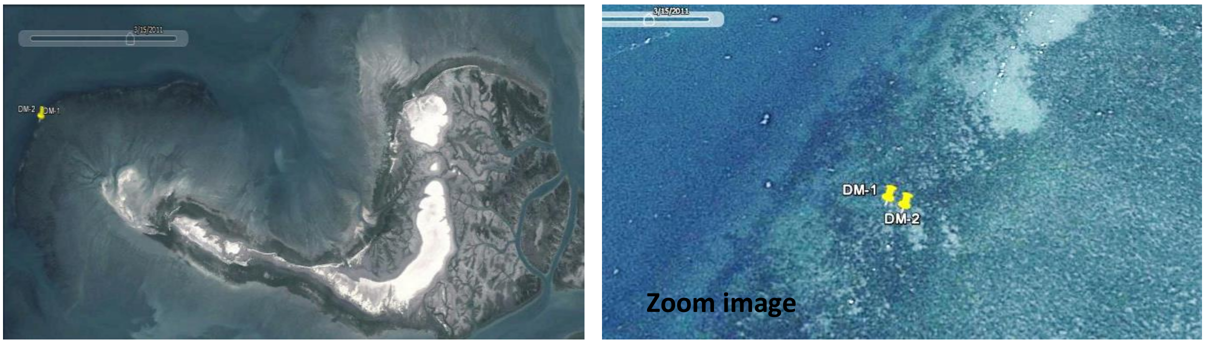


Figure 5.18: Sampling points on Dedeka-Mundeka

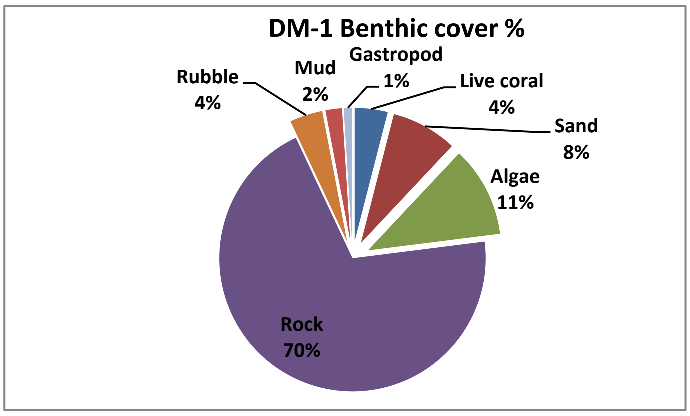


Figure 5.19 % Coverage of benthic components at Dedeka-Mundeka

Table 5.12 Core morphology-DM-1

Core Code & GPS	DM-1 N22° 32' 27" E69° 50° 26.6"
Location	Dedeka-Mundeka
Core length	55 cm
Drilling depth	59 cm
Core recovery	93.22
Breakage (cm from top)	3 breakages(natural discontinuity) at 3, 12, 21cm
Facies type	Unidentified reef substratum
Growth band pattern	Wavy sedimentation pattern
Growth axis	More or less vertical
Colouration	Earthy grey with fine silt coverage
Perforation	Mollusca perforation
Top-bottom	Rock covered with fine silt
Source	Reef rock
Reef Zone	Reef flat near to edge

DM-1

Description of the sampling point of DM-2:

The sampling point of Dedeka-Mundeka DM-2 also falls in a hard ground but far from the edge compare to the previous point. The uneven surface of the calcareous hard ground made it very difficult to approach to the sampling point with generator and drilling instrument. Live corlas were evident in the rock pools forming massive colonies as well as encrusting hard substratum vertically or diagonally.

Biodiversity: Barnacles and gastropods

Benthic profile of the sampling point:

A 5x5 meter quadrate was laid around the sampling point, which showed maximum benthic cover is reef rock near the drilling point contributing about 57% to the benthic coverage of the quadrate followed by algae, rubble and live coral followed respectively (Figure 5.20). The gastropods are the main calcium carbonate contributor after corals.

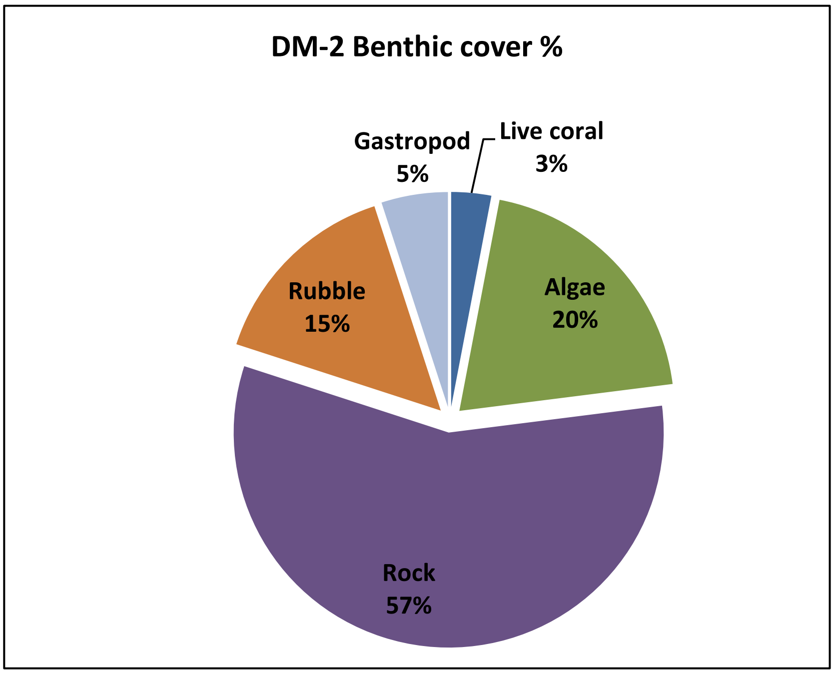
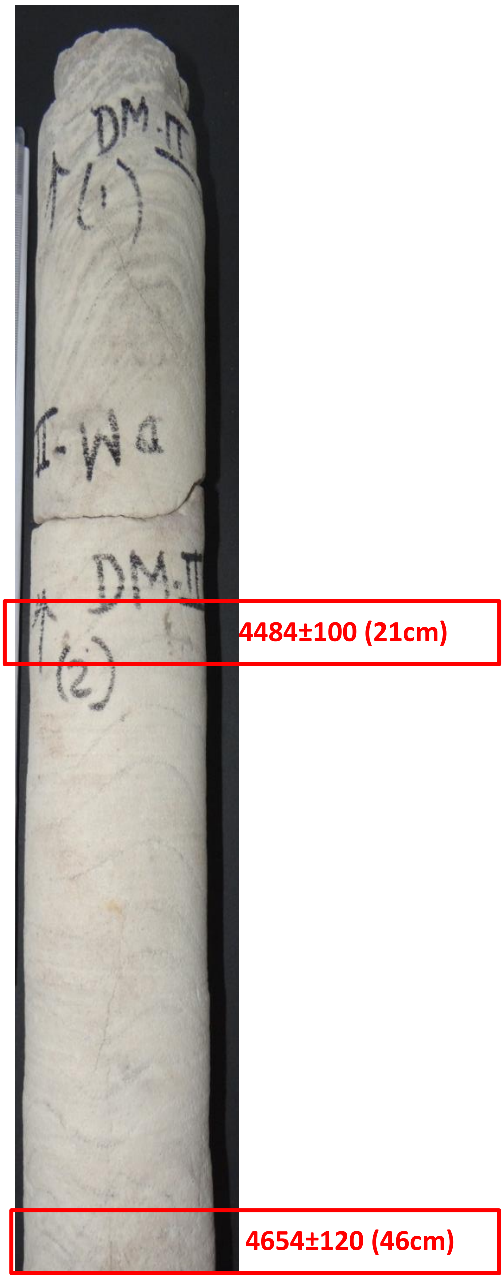


Figure 5.20: Coverage of benthic components at Dedeka-Mundeka

Table 5.13 Core morphology-DM-2

Core Code & GPS	**DM-II;** N22°32' 26.9"E69° 50'26.8"	**DM-2** 
Location	Dedeka-Mundeka	
Core length	44cm	
Drilling depth	46cm	
Core recovery	96 %	
Breakage (cm from top)	1 breakages at 14.5 cm from top	
Facies type	Massive Coral Frame stone	
Growth band pattern	Wavy growth bands	
Growth axis	More or less vertical	
Colouration	Earthy grey at bottom ad dark lines along with bands at top	
Perforation	Not found	
Top-bottom	Green algae at top	
Source	Reef rock	
Reef Zone	Reef edge	

5.2 Radiocarbon Dating for Age Analysis of the Cores

Radiocarbon age and east-west trend

A total of 32 samples, derived from cores were sent to BSIP, out of which 8 samples were modern and the age of the rest samples range between 5844 years Before Present (BP) to 1134 years BP (Table 5.1). These analysed samples give a brief idea on the accretion rates of 12 cores out of 13 collected cores. As per the analysis carried out, the oldest sample is of the Goose reef core -1 *viz*, 5844 years BP (GS-1 sample depth = 56 cm) and the youngest sample also belong to goose reef but another core *viz*, 1134 ± 80(GS-2 sample depth = 25 cm). The three oldest samples GS-1, followed by KL-2, followed by NR-1 and DM-2 are falling in the eastern zone of the GoK whereas most of the samples from western zone show radiocarbon ages less than or around 4000 years BP(Figure 5.21). However, there is a poor correlation (r) = 0.2 between the west-east progression with the age increment (Figure 5.22).

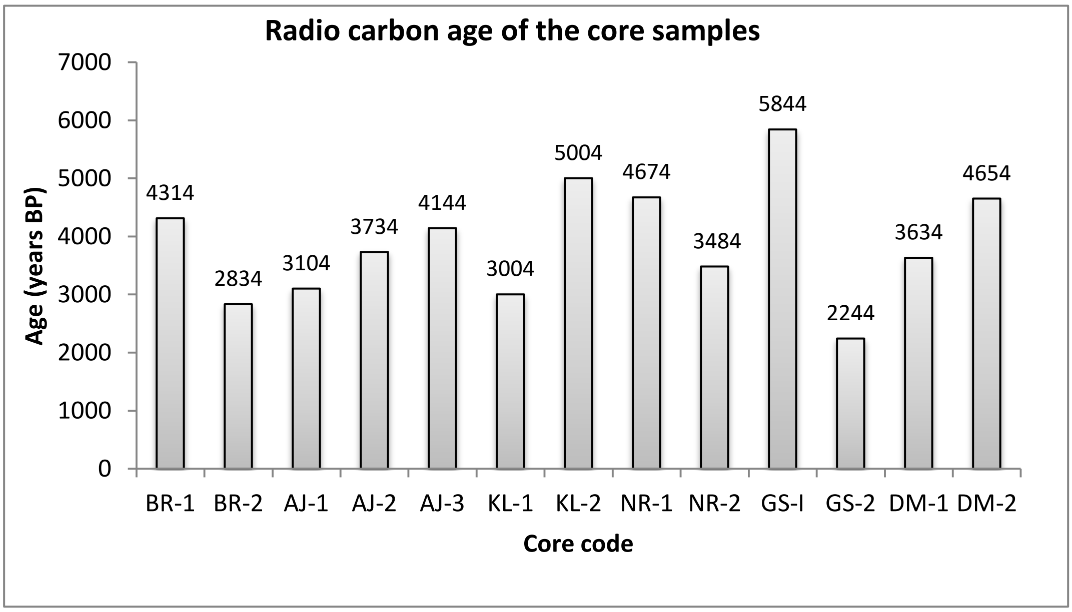


Figure 5.21 Radio carbon age (oldest) of the coral core samples from the Gulf of Kachchh

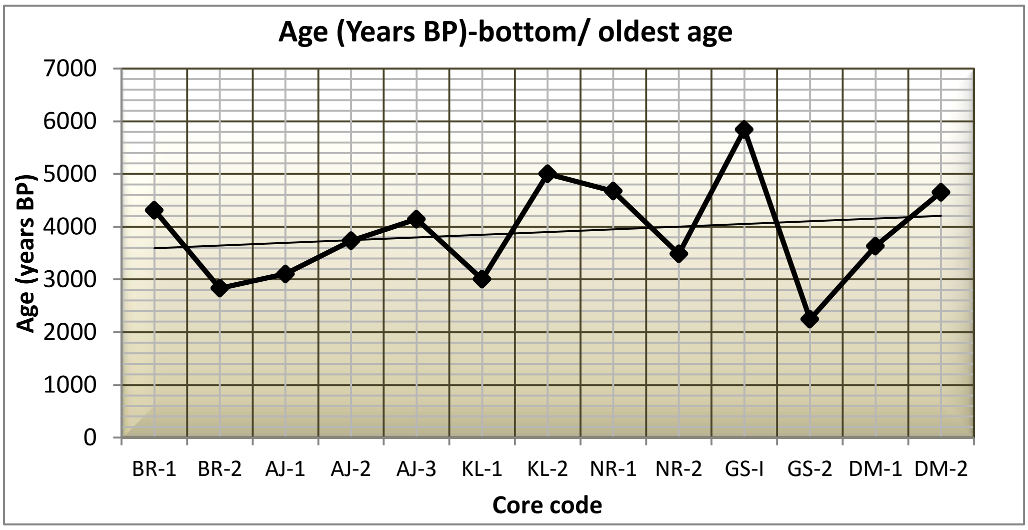


Figure 5.22 Radio carbon age-showing west to east trend in the Gulf of Kachchh

Discontinuous chronology/Age Reversals

While studying coral reef stratigraphy, researchers come across age reversals or discontinuity in chronology. Such incidents disrupt accurate interpretation of reef growth, unless rectified. The present study has also revealed such age reversals as shown in Figure 5.1 where the bottom was found as modern sample (here modern means anywhere during the past 2 hundred years or so approximately and we can't tell whether it was formed yesterday or 200 years ago). Hence, they were rectified by changing the directions of chronology interpretations and the opposite ends of the core were sub-sampled for radio carbon dating. There are a number of mechanisms leading to such disturbances in natural formations of the reef.

1. The coral head toppled due to extreme wave action and newer/ younger corals may have established over the toppled segment of reef.
2. The growth axis of corals is not only vertical; hence a single slice through a coral colony might reveal older growth on top of younger growth (Rees, 2005).
3. Coral growth or deposition of younger material beneath overhangs. Older fragments of corals being re-worked to a deeper but younger growth horizon for example from reef crest to reef slope (Rees, 2005).
4. Older coral fragments being re-worked to a younger growth horizon, for example, thrown-up coral blocks onto reef flats during storms and cyclones (Rees, 2005).

Table 5.14 Ages of various core samples

Sr. no.	Core code	Core length(cm)	Sample position (top=0cm)	Age (BP)
1	BR-1	104	104	4314±110
2			75	4184±110
3			50	3784 ±90
4			25	3804 ±90
5	BR-2	66	66	Modern
6			25	Modern
7			0	2834±70
8	AJ-1	57	57	3104±120
9			32	1964±90
10	AJ-2	71	71	3734±100
11			46	3424±100
12	AJ-3	90	90	4144±120
13			65	3324 ±100
14	KL-I	67.7	67.7	Modern
15			25	Modern
16			0	3004±100
17	KL-II	56.5	56.5	5004±120
18			31.5	5004+100
19	NR-I	92.5	92.5	4674±100
20			67.5	Modern
21	NR-II	89	89	Modern
22			25	3484 ± 120
23			0	3164 ± 120
24	**GS-I**	**56**	**56**	**5844±110**
25			31	1544±90
26	GS-II	87	87	Modern
27			**25**	**1134 ± 80**
28			0	2244 ± 100
29	DM-1	55.8	55.8	3634± 100
30			0	Modern
31	DM-II	46	46	4654±120
32			21	4484±100
Total sent: 32			**Total analysed: 32 (24 dates +8 modern)**	

Age and depth

The samples of the 13 cores were procured from various depth and the radiocarbon ages vary according to sample depth ranging from 0 to 104 cm from surface (Figure 5.23). The depth range from 0 to 104 was subdivided into 21 depth ranges where each part is of 5 cm. Out of the 21 depth ranges, radiocarbon age is found falling in 10 ranges only. Maximum samples were derived from the depth range 55-65 cm and 0-5 from the surface. In the Gulf of Kachchh, the oldest samples were achieved from the depth range of 55-60 cm *viz.*, two of the samples crossing age of 5000 year BP one from GS-1 and the other from KL-2. Additionally, the samples from the depth range 30-35 and 40-45 showed age between 4500 year BP to 5000 year BP whereas the minimum age were procured from the depth range of 20-25 cm.

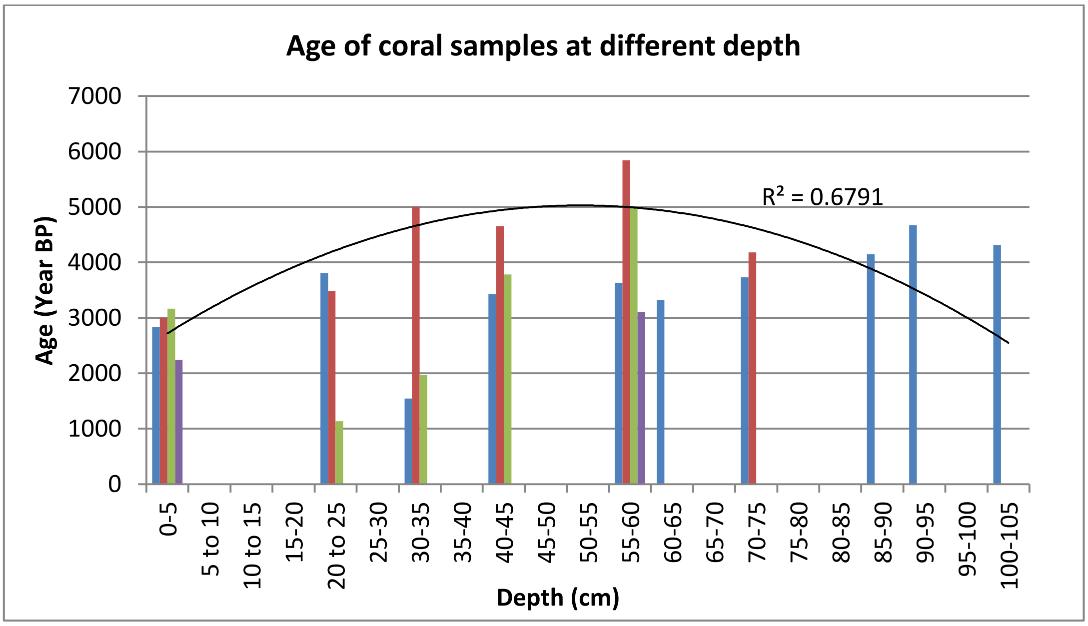


Figure 5.23 Showing the age of different coral samples at various depth ranges in the Gulf of Kachchh (Depth class each of 5 cm)

In order to assess correlation of the age and depth of the collected samples, the ages of the samples were averaged out at each depth range (a total of 21 depth ranges). Logically, the sample ages should be directly proportionate to sample collection depth. The radiocarbon ages of the samples vary at different depth and as per the results (Figure 5.24), the average of the age is increasing with the depth but again show a slight fall after the pick of 55-60 cm depth range, hence the data shows best fit of polynomial trend (R^2 0.7073) for the 10 depth ranges.

The reason for not exactly fitting the data in linear trend is the difference in the sites *i.e.*, at some of the sites the deeper samples are yielding younger ages and in case of Goose and Kalubhar the samples from lesser depth yielded very old ages indicating the slower accretion rate that further may be a function of a number of natural and anthropogenic factors, affecting calcium carbonate depositions.

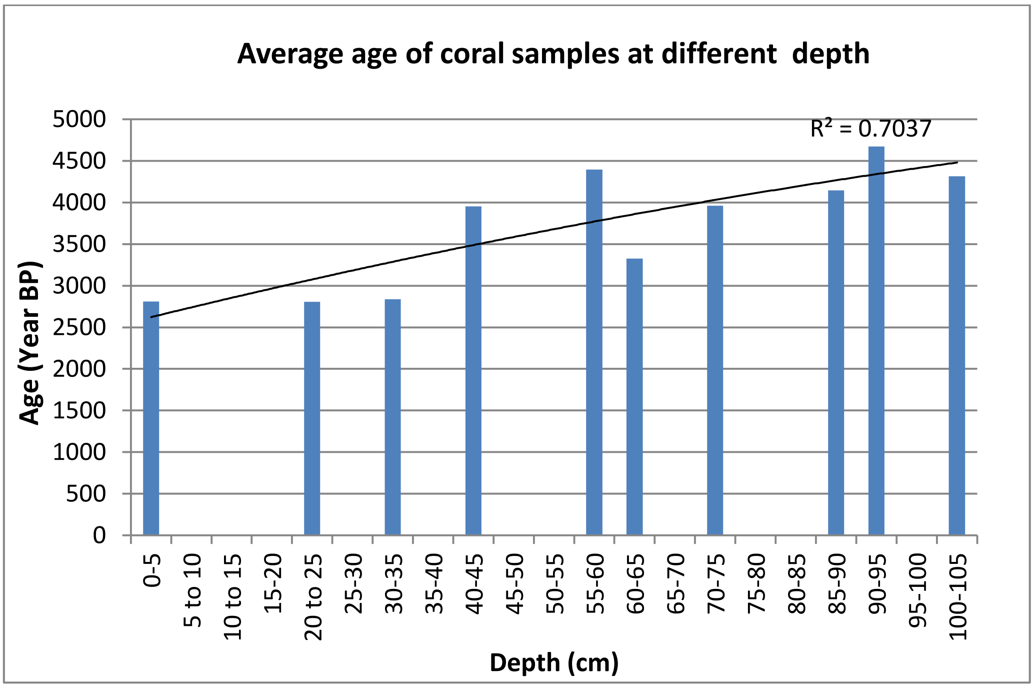


Figure 5.24 Showing the average of coral sample ages at various depth ranges in the Gulf of Kachchh

Vertical Accretion Rate

The age of the samples collected from the pre-defined points of the cores, provided the growth rate of that particular core in a definite period of time *i.e.*, accretion rate of reef in upward direction. Vertical Accretion Rate (VAR) is defined as the positive balance between constructive and destructive processes acting on the reefs (Gherardi and Bosence, 2005). For this instance, it is measured in the vertical direction of reef growth, and expressed as millimetres per year in the present analysis (Table 5.2).

Table 5.15 Accretion rates of various core collected from the Gulf of Kachchh

Sr. No.	Core code	Average Accretion Rates of core(mm/years)
1.	BR-1	1.03
2.	BR-2	0.16
3.	AJ-1	0.22
4.	AJ-2	0.47
5.	AJ-3	0.30
6.	KL-1	0.15
7.	NR-1	0.05
8.	NR-2	0.78
9.	GS-1	0.13
10.	GS-2	0.23
11.	DM-2	0.76
12.	DM-1	0.15
Average		**0.37**

The accretion rates of the 12 cores have been calculated based on the analysed dates. The core from the Boria (BR-1) has the highest accretion rate and one of the core from Narara (NR-1) has the lowest accretion rate, however another core from Narara had the second highest accretion rate among all the cores (Figure 5.25). The average accretion rate of the cores calculated is 0.37 mm/years. Some of the cores had 3 samples analysed or 2 analysed and the rest had been assumed modern (due to its position as the "surface" or as top of the drilled core), based on which 2 accretion rates have been derived and averaged out for each core. The accretion rate of the cores namely NR-2 and DM-2 are nearly equal and second highest among the 12 cores, followed by AJ-2 core from the Ajad Island. The west to east progression of the accretion rate has shown a negetive correlation (r= -0.18) that means moving from west to east, there exists a decrement in the accretion rate of corals, notwithstanding the weak proportion.

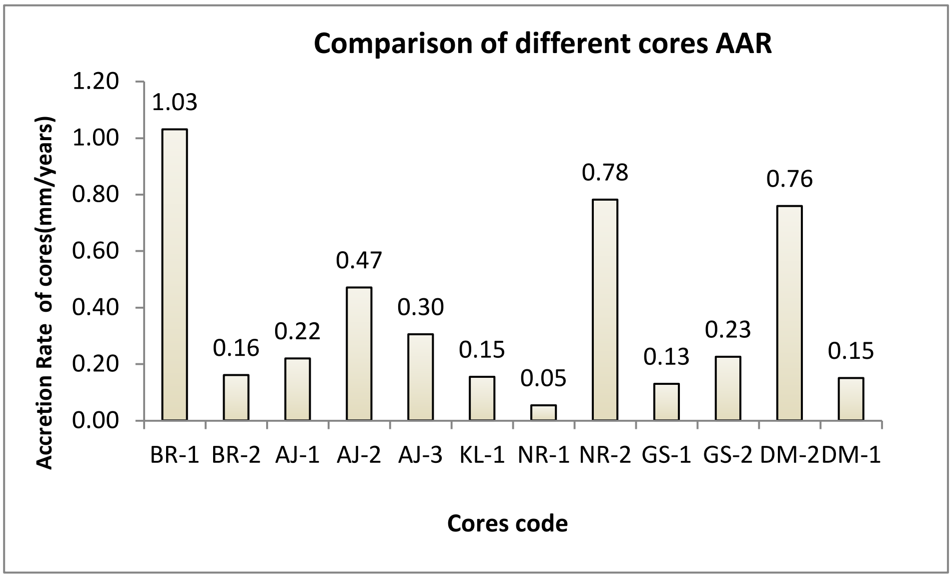


Figure 5.25 Comparison of Average Accretion Rate (AAR) of cores collected from the GoK

A preliminary study of the present project was carried out by Pandey, *et al.*, 2010 which revealed the accretion rate of 4 samples from the GoK ranging from 0.247 mm/years to 0.024mm/years. They derived the VAR of Goose to be 0.24mm/years, collected from the depth of 50 cm from surface; it is in line with the present study which revealed the VAR of Goose core to be 0.23 mm/years. However, the average accretion rates of both the cores in present study vary from the results of Pandey *et al*., 2010.

The accretion rates of the Gulf of Kachchh can be divided into 3 major classes and total 7 classes (Figure 5.26). The three major classes are 0.10 to 0.19 mm/years, 0.45 to 0.50 mm/years and 0.75 to 0.80 mm/years collectively they encompasses 8 cores. A total of four cores are showing accretion rate between 0.10 to 0.19 mm/years and rest two classes include 2 cores each. Except these three classes, remaining four classes involve one core in each class.

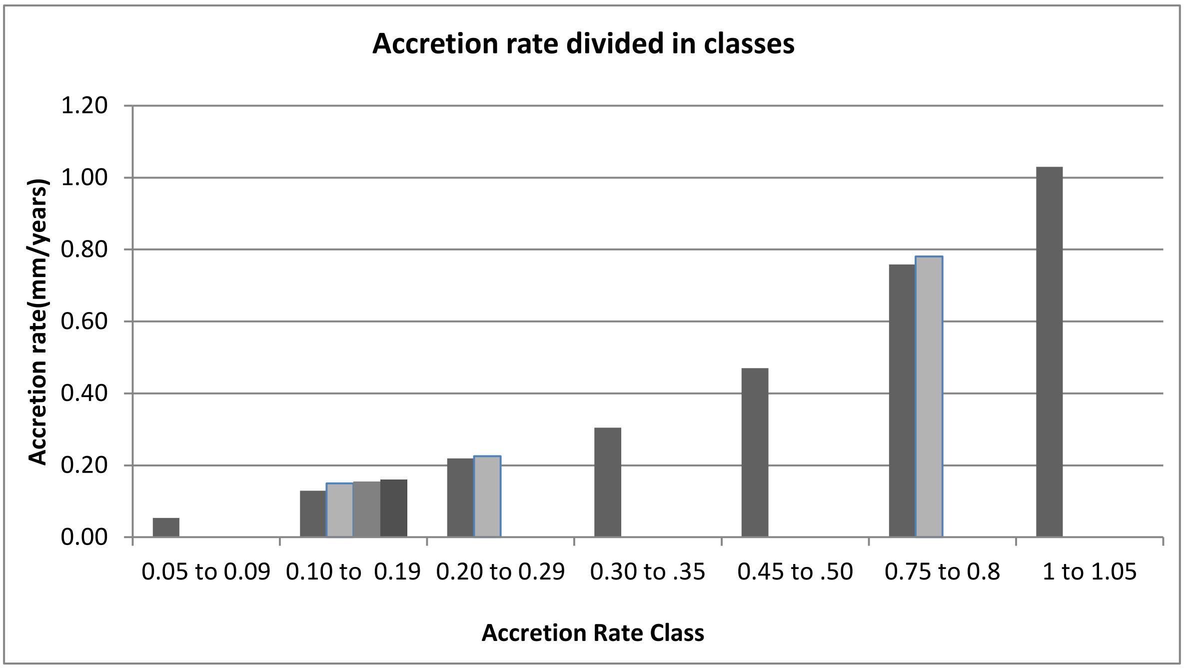


Figure 5.26: Average Accretion Rate (AAR) of various cores collected from the GoK

Gherardi and Bosence (2005) reported Vertical Accretion Rate (VAR) of six cores collected from 1-m depth from windward, leeward and intertidal hardground environments of oceanic atoll Atol das Rocas. They found the VAR falling in three ranges *i.e.*, 0.25 mm/years to 0.46 mm/years, 0.85 mm/years to 1.6 mm/years, 3.2 mm/years to 18.4 mm/years (Table 5.3). Grossman and Fletcher, 2004 analysed 32 drill cores obtained from the windward reef of Kailua Bay, Oahu, Hawaii and found the coral frame stone accretion rate to be 2.5 to 6 mm/years in water depths 11 m during the early Holocene; it abruptly terminated at 4500 years BP because of wave scour as sea level stabilized. While comparing the VAR of GoK with the published available literature (Gherardi and Bosence, 2005; Grossman and Fletcher, 2004), the VAR of GoK is low. The corals grow well till the tidal water permits to survive at the shoreward side and hence, the corals are considered as the indicators of then prevailing sea level. After some level of growth, corals are known to grow laterally with flat tops (Michael *et al.*, 2009). This type of growth form was also recorded during the present study. The live coral colonies were found to have limited vertical growth ranging from 20 cm to 60 cm based on the habitat *i.e.*, colonies at shallow reef flats had less vertical growth and colonies growing inside the tidal pools with 30-60 cm depth showed higher vertical extension. In the GoK, after attaining growth up to water surface level height, the coral colonies stops growing vertically and their horizontal growth increases with dead or flat tops (Figure 5.27). The coral colonies in the Figure 5.27 are growing healthily and one of them is having diameter of 1 meter but the direction of growth is horizontal their top portions are either dead or flat (Plate 5.1).

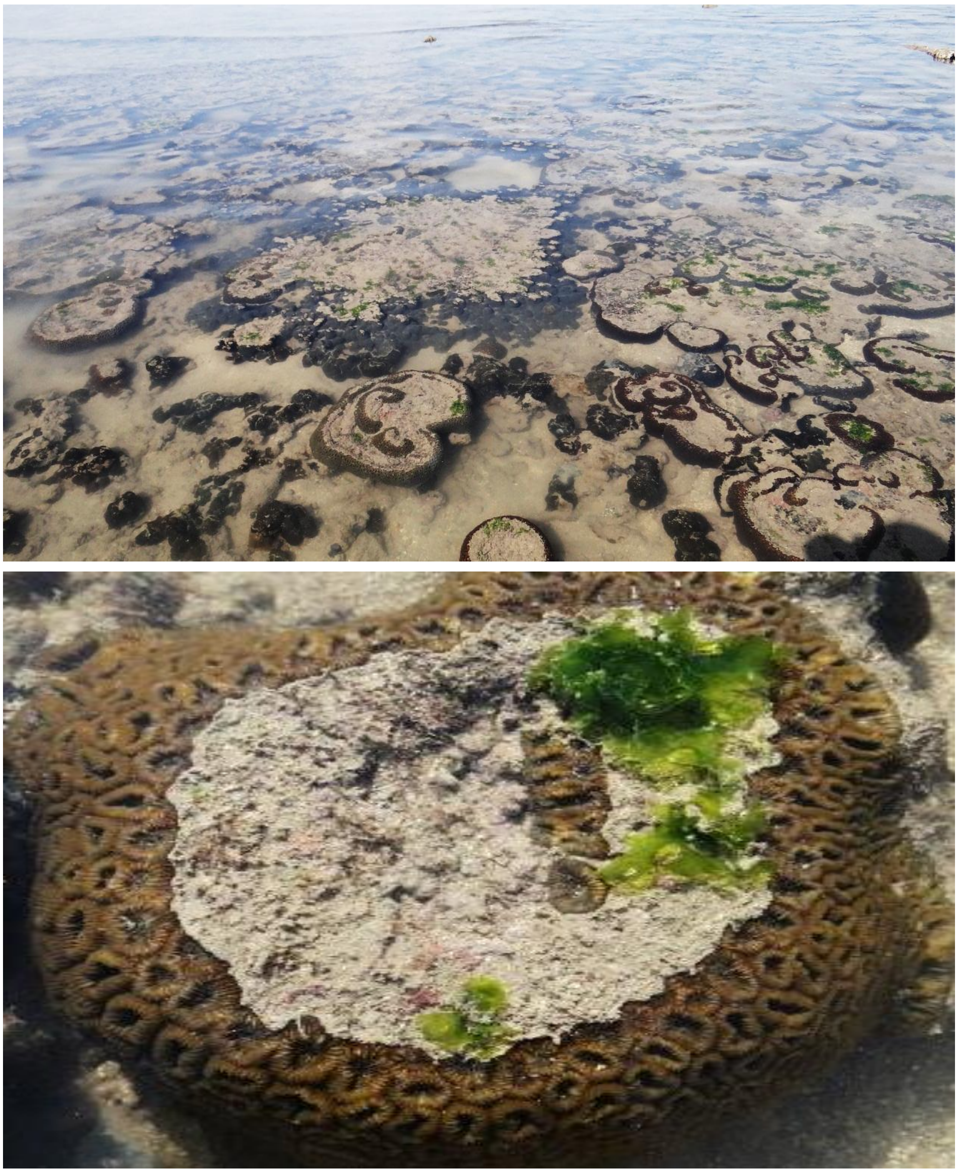


Figure 5.27 The typical growth form of the coral colonies of the GoK

Plate: 5.1: Coral growth form at various succeeding stages

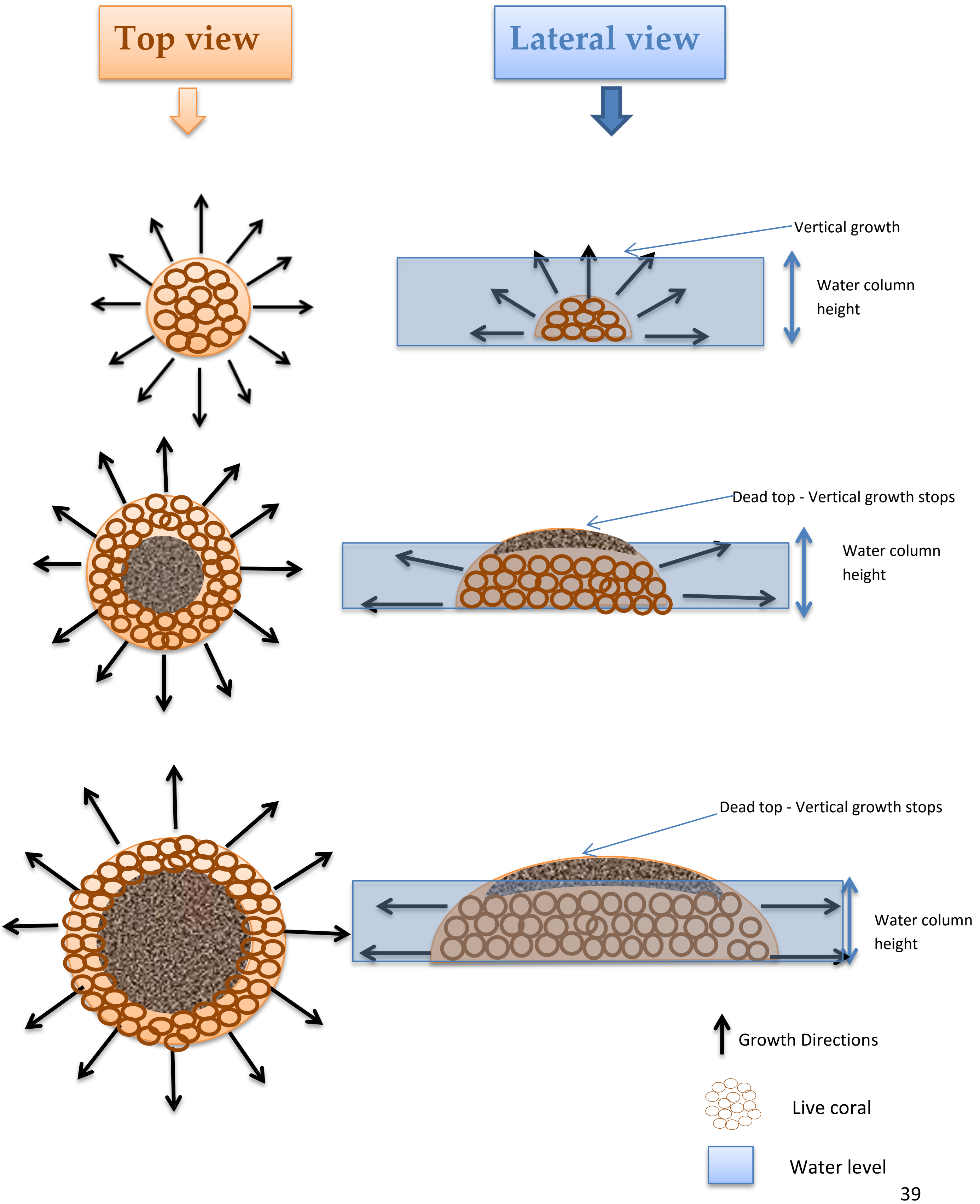


Table 5.16: The comparison of VAR of GoK with the other parts of the world (**Rees et al, 2005;** species detail source: Fenner *et al*, 2004); **Gherardi and Bosence, 2005; Grossman and Fletcher, 2004;** Kikuchi and Leao 1997)

Location	VAR - mm/years	Species	Reef type and Reef region (Spalding *et al.*, 2001)
Gulf of Kachchh, Gujarat, India	0.37	Coral frame work, coralline algae	Patchy, platform reefs; Southeast Asia (Indo-Pacific)
Rodrigues, Indian ocean	0.68 1.2 0.46 **1.96** 0.92 1.7	*Acropora abrotanoides and Acropora austera* (dominated) the tops of ridges	Atoll; Indian Ocean (Indo-pacific)
Average	**1.1**		
Oceanic atoll: Atol das Rocas, South America	0.25 to 0.46 0.85 to 01.6 **3.2 to 18.4**	Coralline-algal frameworksPorolithon cf. pachydermum, Lithophyllum sp.	Atoll; Atlantic Region
Average	**4.1**		
Kailua bay, Hawaii, U.S.A.	1.1	*Porites compressa*	Fringing reef; Pacific (Indo-Pacific)
	2.17	*Porites compressa*	
	0.64	*Porites lobata (Massive)*	
	1.04	*Porites lobata(Encrusting)*	
	0.24	*Montipora patula*	
	2.05	*Porites compressa*	
	1.59	*Porites compressa*	
	2.72	*Porites compressa*	
	4.08	*Porites lobata (Mass.)*	
Max.	**6.91**	***Porites compressa***	
	4.52	*Porites compressa*	
	2.53	*Porites lobata (Mass.)*	
	1.38	*Montipora patula*	
Average	**2.4**		
Atol Das Rocas reefs	**1.5 - 3.2**	*Siderastrea stellata*	Atoll; Atlantic Region
Average	**2.35**		

Vertical Accretion Rate-site wise scenario

In order to give a site specific scenario of the coral reef accretion rate in the Gulf of Kachchh, the accretion rate of all the cores of a single site were averaged out (Figure 5.28). The comparison of all the sites shows the highest accretion rate at Boria and the lowest at Kalubhar, same as in the case of individual cores. The accretion rate of Narara and Dedeka-Mundeka are nearly equal *i.e.*, 0.42 and 0.45 mm/years. The trend of accretion rate from west to east has shown a weak correlation with direction (r = -0.3) but stronger than the individual cores. This correlation is also showing a negative value that indicates decreasing trend of the accretion rate from west to east.

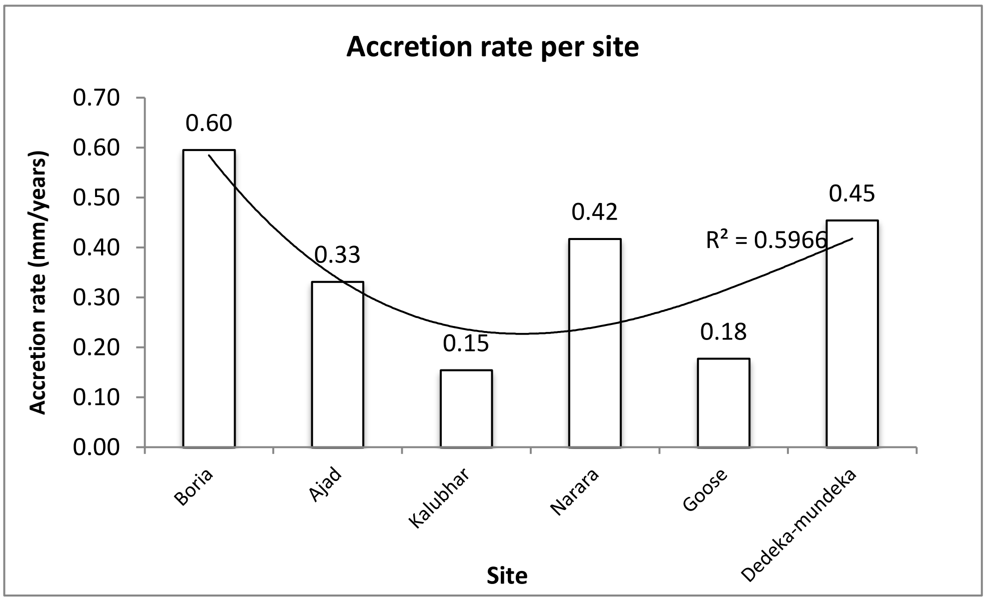


Figure 5.28 Average Accretion Rate (AAR) of various Sites with west-east trend in the GoK

As discussed earlier, the samples from less depth at the eastern zone of the Gulf of Kachchh were older (showing higher age) compare to the deeper samples from western zone. The fact indicates higher accretion rate at western zone of the Gulf of Kachchh. The same fact is also reflected by the accretion rate data west-east trend in the Gulf of Kachchh.

Age class and accretion rate

In order to know the reef accretion rate at various time periods, the accretion rates of the cores were divided into 12 class *viz.*, 0-500,501-1000 up to 5501 to 6000years BP. This information will consequently reflect the time period when the coral reef of Gulf of Kachchh had experienced the optimum environmental conditions and consequently achieved highest accretion rate throughout last 6000 years BP to till date during the Holocene. The results show a polynomial trend of the data *i.e.,* the observations are showing highest pick at 4000 to 5000 years BP and the initial and ending data has comparative low value. This implies the coral reefs of the Gulf of Kachhh had experienced the most favourable conditions during the 1000 years period before 4000 to 5000 years BP. The samples from Boria and Dedeka-mundeka have yielded maximum accretion rate during the period of 4000 to 5000 years BP. However, the average Accretion rate at each class has provided three pick in the data that shows the accretion rate of the coral reefs had a rise at 5000 to 4500 years BP, 4500 to 4000 years BP and 1500 to 1000 years BP (Figure 5.29). The eustatic studies show that, on the Arabian Peninsula, the Holocene sea transgressed inland approximately 7 ka BP that continued until 4 ka BP, Figure 5.29 (Mathur *et al.,* 2004). The evidences also suggest that the sea level was 1–4 m higher along the Indian coast during Middle and Late Holocene (Mathur *et al.,* 2005). Middle and late Holocene involves years 5 ka BP and the year following the same. The results of the present study show that increment in VAR is following the period of sea level rise, as if the rise in water level may have provided an opportunity to the coral colonies to grow upward.

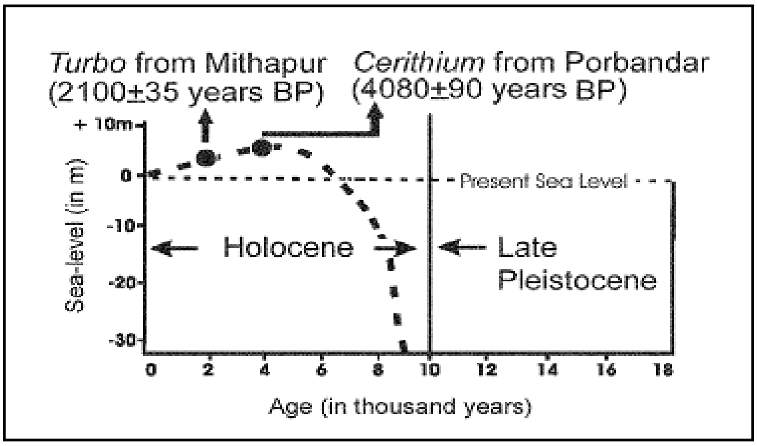


Figure 5.29 Holocene sea level rise and fall (Mathur, 2003)

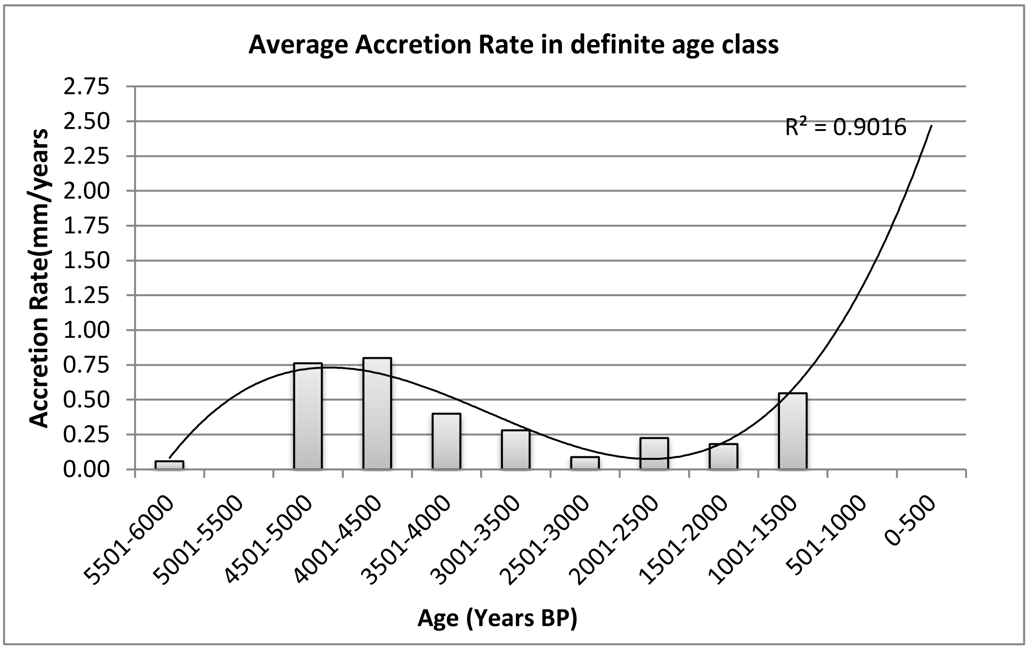


Figure 5.30: Accretion Rate of various samples in definite age class in the Gulf of Kachchh

As per the available results, the highest accretion rate is found between 4000-5000years BP in the GoK however, maximum samples analysed belong to the period 3000-3500 years BP that includes 26% of the total samples; followed by the period 4000-4500 years BP and 3500-4000 years BP (Figure 5.30, 5.31). This may be the indication of overall favourable conditions during 3000-3500 years BP.

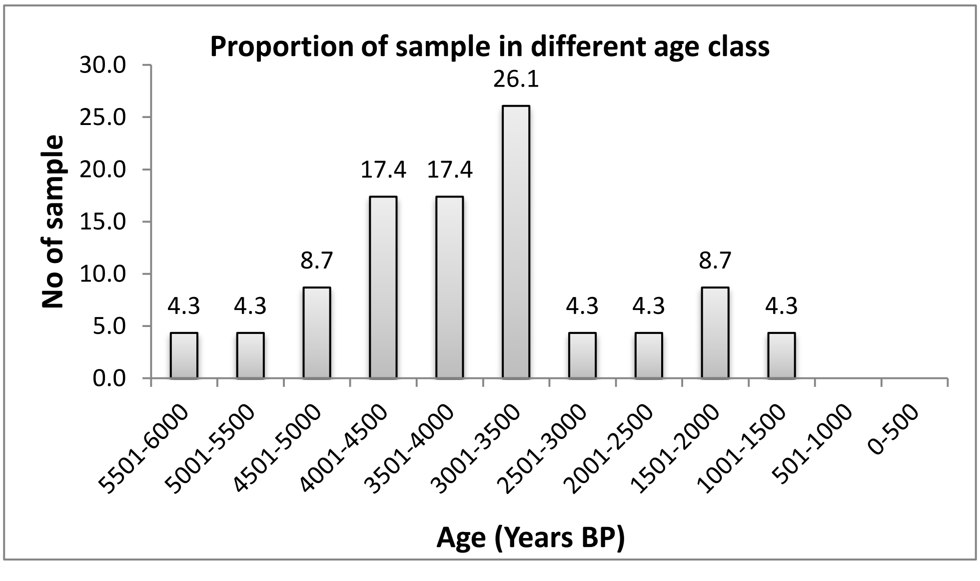


Figure 5.31 Sample % contributions in definite age class in the Gulf of Kachchh

Carbon Storage Potential of the Coral Reefs of Gujarat

Carbon in the collected samples

The carbon storage potential of any reef is its ability to accumulate organic as well as inorganic carbon as a consequence of biological or bio-geochemical processes. As majority of the sample material in the present study was of coral origin, its chemical constitution is mainly calcium carbonate hence the inorganic carbon is taken in consideration i.e., 12% (by weight). The weight of the collected samples (except DM-2) is 50.13 kg which implies 6 kg of inorganic carbon sequestered in it (Table 5.4).

Table 5.17 Details of the collected coral core samples from the GoK

Core code	Core length(cm)	Volume (cm^3)	Weight (kg)	Carbon/core (kg)
BR-1	104	4000.36	6.400576	0.8
BR-2	66	2538.69	4.061904	0.5
AJ-1	57	2192.505	3.508008	0.4
AJ-3	60	2307.9	3.69264	0.4
KL-I	67.7	2604.081	4.1665288	0.5
KL-II	56.5	2173.273	3.477236	0.4
NR-I	92.5	3558.013	5.69282	0.7
NR-II	89	3423.385	5.477416	0.7
GS-I	56	2154.04	3.446464	0.4
GS-II	87	3346.455	5.354328	0.6
DM-II	46	1769.39	2.831024	0.3
AJ-2	33	1269.345	2.030952	0.2
	Total	**31337.44 cm^3**	**50.14 kg**	**6.0 kg**

Carbon storage potential of the coral reefs of Gujarat and its fate

Based on the accretion rate of the coral cores and carbon proportion in the $CaCO_3$, the carbon storage potential of the coral reefs of GoK is 25041.60 ton Carbon per year *i.e.,* the coral reef of GoK sequestrates 25041.60 ton Carbon in the form of calcium carbonate annually. According to this, the coral reef will sequestrate approximately 2504160 ton carbon in the next century.

The annual carbon increment has been calculated by the following formula:

Annual Carbon storage = Annual Accretion rate x Reef area x density x %Carbon (12) *

* The results are subject to the reef area at present and its condition in future

Contribution in carbon storage of the state-Gujarat

Annual carbon dioxide emission of Gujarat is calculated to be 143 X 10^6 ton during 2009 (*Rajpurohit and Dutt, unpublished*) that corresponds to 386 X 10^5 ton carbon per year. The annual carbon absorption of coral reefs of Gujarat is 25041.60 ton Carbon per year. Hence, the carbon sequestration of the coral reef corresponds to 0.065 % of the Carbon emission of Gujarat.

Contribution in carbon storage of the Country-India

The national scenario is, annual carbon dioxide emission of India is calculated to be 190.47 X 10^7 ton during 2007 (MoEF, 2010) that corresponds to 514 X 10^6 ton carbon per year. The annual carbon absorption of coral reefs of Gujarat is 25041.60 ton Carbon per year. Hence, the carbon sequestration of the coral reef corresponds to 0.005 % of the Carbon emission of India.

However, other sinks such as mangroves, sea-grass, seaweeds and other photosynthetic organisms are not included in these assessment, the calculations are exclusively for coral reefs.

Carbon storage Potential-during different time period

The calcification rate of any coral reef is subject to a number of physico- chemical and oceanographic factors. That consequently affects the potential of inorganic carbon sequestration that is mainly stored in the reef as a part of each $CaCO_3$ molecule formation. The affecting factors vary with the time passage hence, the carbon storage potential varies during various age classes (Figure 5.32). Based on the present results, the highest carbon has been stored during 4000-5000 years BP followed by the period of 500-1000 years BP.

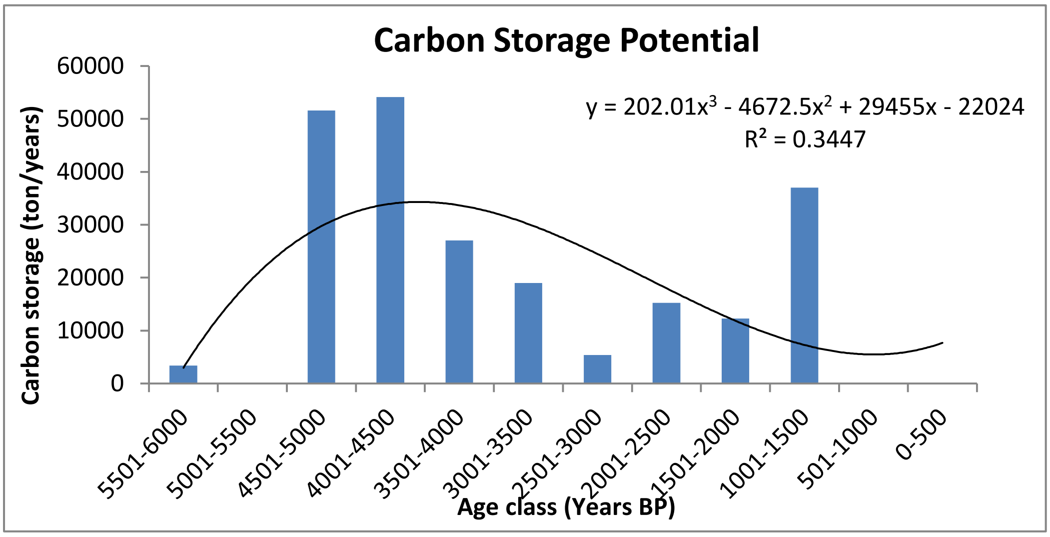


Figure 5.32: Carbon stored by the coral reefs during different age classes in the GoK

5.3 Occurrence of mass Coral Bleaching in the GoK

The corals are potential bio-markers of the environmental stresses which gets reflected in the form of coral bleaching evidences. The impacts of thermal stress were clearly evident in the form of mass coral bleaching at the reefs of the GoK during the present survey. The mass coral bleaching at varying degree was observed on the reefs of the GoK during the summer months of the year 2010, 2013 and 2014.

Occurrence of coral bleaching was evident at both the sites. The corals showed recovery at the subsequent visits of post-monsoon. However, the severity of the mass coral bleaching was the highest in 2010 (Plate 5.3, Plate 5.4). All the scleractinian growth forms were observed suffering from moderate to severe bleaching. A total of 19 coral species belonging to 13 genera and 7 families were affected (Figure 5.33; Table 5.5). The bleached corals include four near threatened and one vulnerable species (http://www.iucnredlist.org). The extent of bleaching varied among different colonies and even the same species showed difference in bleaching intensity (Plate 5.2). Most of the *Porites* colonies were found to be partially recovered in the October, 2010 but showed complete recovery only in the month of November, 2010.The branching coral species are more bleaching prone and fragile than the massive species like *Porites* (Baird and Marshall, 2002) and hence, even after delayed recovery of more than 100 days, *Porites sp.* could survive completely and no mortality was found. After that, consequent years also showed mass coral bleaching however during 2013 and 2014, a total of 13 and 9 coral species were found bleached. However, there is a significant difference between the number of species affected each year (p value for the 2 consecutive years equals to 0.0018, 0.008 and 0.0003). This difference gets justified by Plate 5.5; It shows the highest differences in extremity of the years that means highest SST in 2010 followed by 2013 and 2014 (Figure 5.35; Plate 5.5).

The annual mean SST of the GoK ranges between 26.04°C (1985) to 26.10°C (2005) with the annual minimum 23°C and maximum 28.9°C. The annual mean SST of the last two decade from 1990 to 2010 have shown highest thermal anomalies in the GoK during 2010 (Figure 5.34). The annual mean SST and annual thermal anomalies of the year 2010 are exceeding even the 1998 SSTs (www.oceanmotion.org). Therefore, the biological consequences of 2010 might be similar or rather worse than 1998 in the GoK which might be reflected in the form of mass coral bleaching. In accordance with this, the Global Coral Reef Alliance (GCRA) predicted 2010 to be, one of the worst coral bleaching years ever (www.globalcoral.org). The thermal threshold for the GoK reefs is estimated to be 30°C (Vivekanandan *et al.*, 2008). The monthly mean SST of the GoK during May and June, 2010 was 30°C and 32°C respectively which is crossing thermal threshold in 2010 (www.esrl.noaa.gov). The monthly mean SST of the GoK during May and June, 2013 was 28.67°C and 30.45°C respectively which is also crossing thermal threshold (http://oceanmotion.org/html/resources/ssedv.htm). The monthly mean SST of the GoK during May and June, 2014 was 28. 7°C and 28.9 °C respectively, that is comparatively less than the previous years 2010 and 2013 (http://oceanmotion.org/html/resources/ssedv.htm) The observations of bleaching recovery in the early winter correspond to the decreased SST of the October and November, 2010 *i.e.,* 28.4°C and 28.1°C respectively.

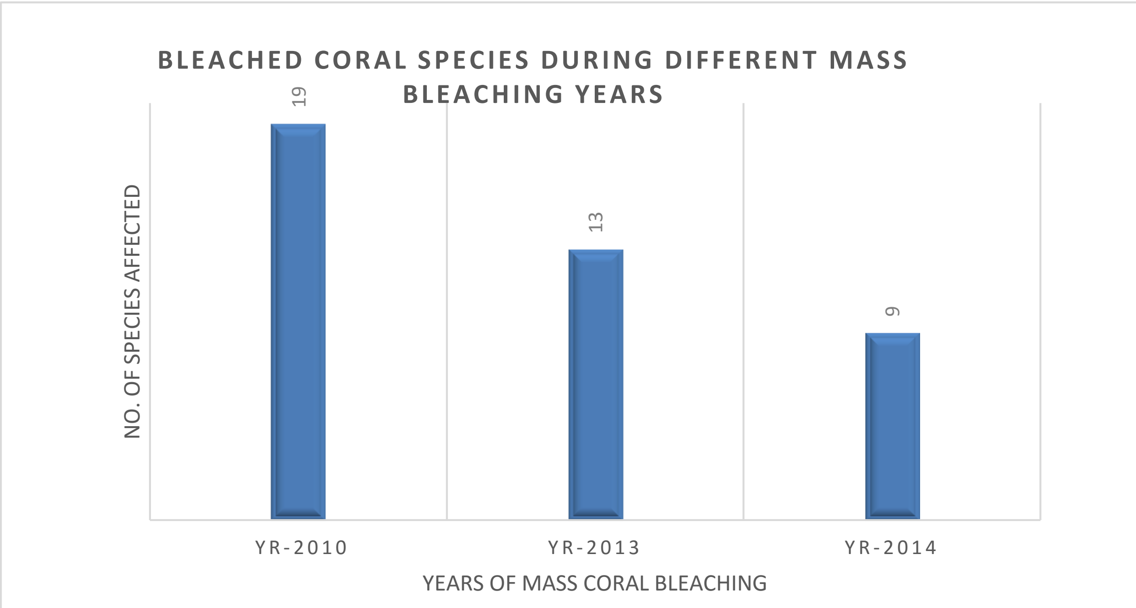


Figure 5.33: Bleached coral species during mass bleaching years

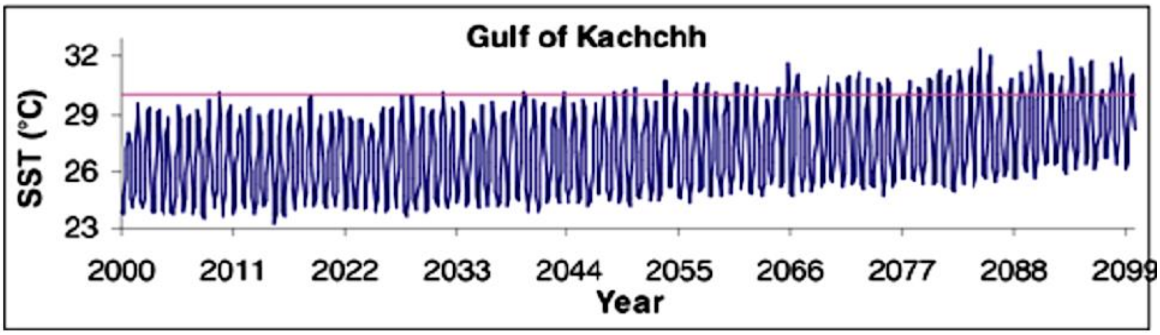


Figure 5.**34:** Showing SST predictions for next century in the GoK (**Source**: Vivekanandan *et al.*, 2009)

Original condition of corals **Bleached coral**

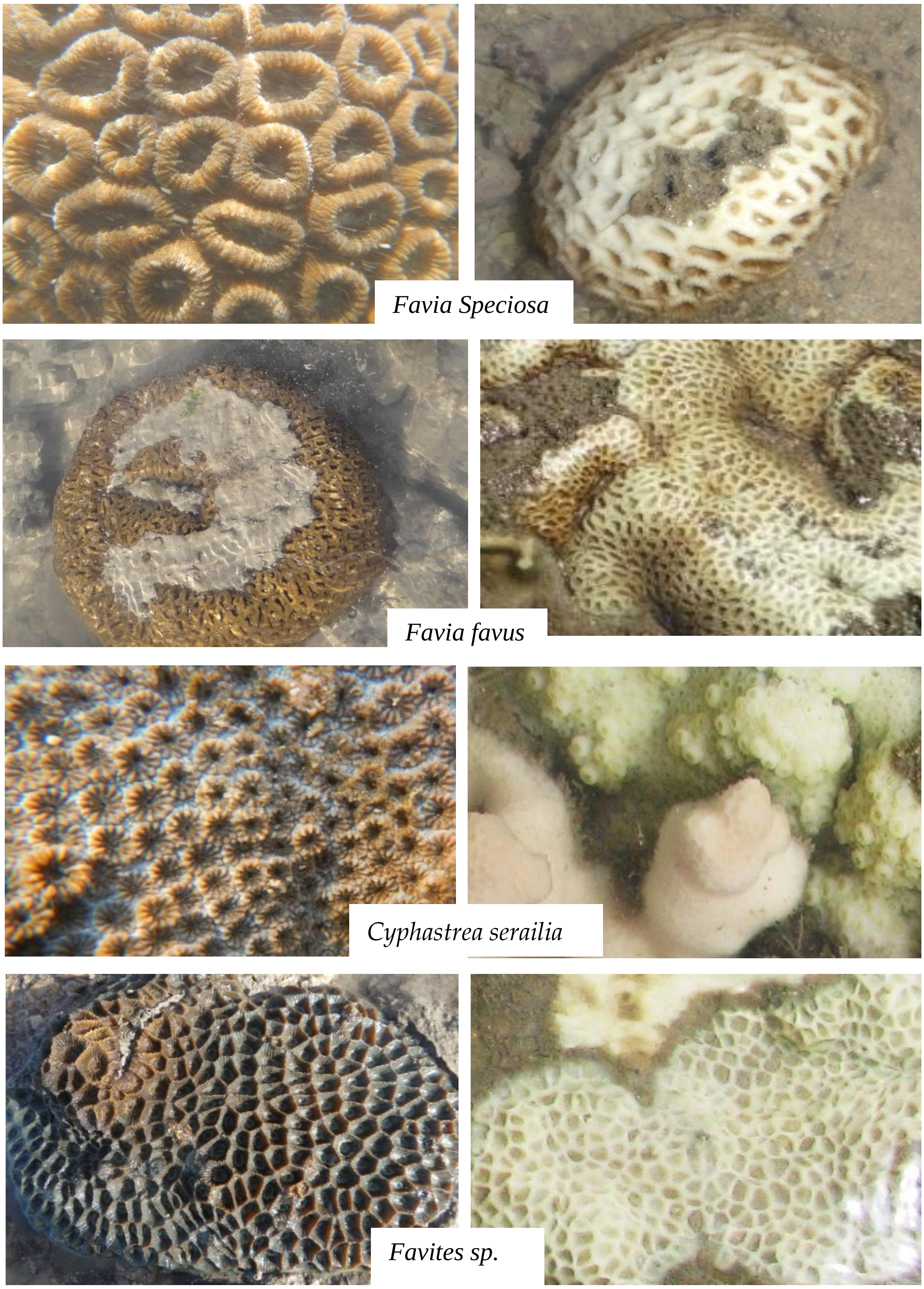


Plate 5.2 (a) Showing original and bleached condition of various coral species

Original condition of corals **Bleached coral**

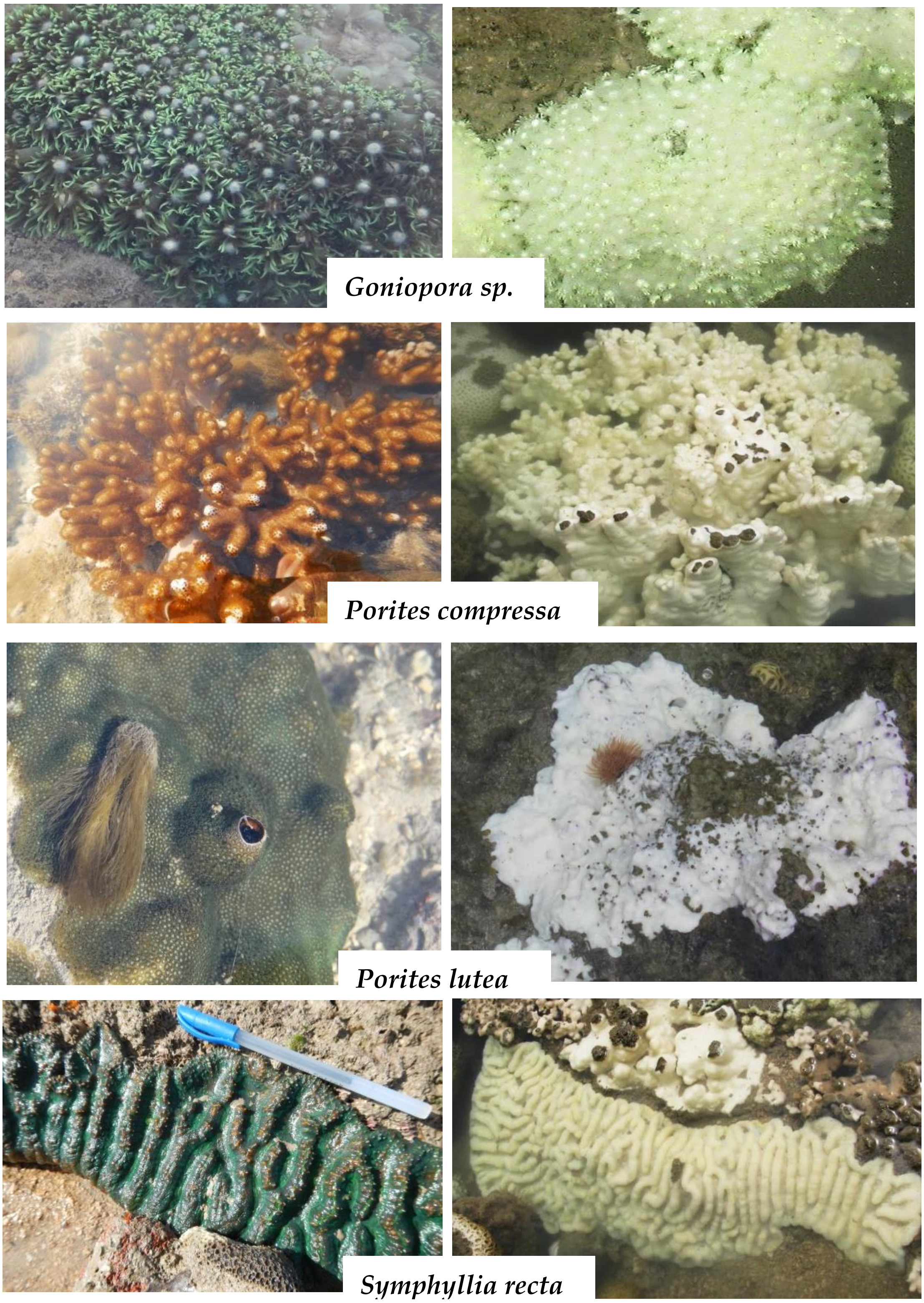


Plate 5.2 (b) Showing original and bleached condition of various coral species

Original condition of corals **Bleached coral**

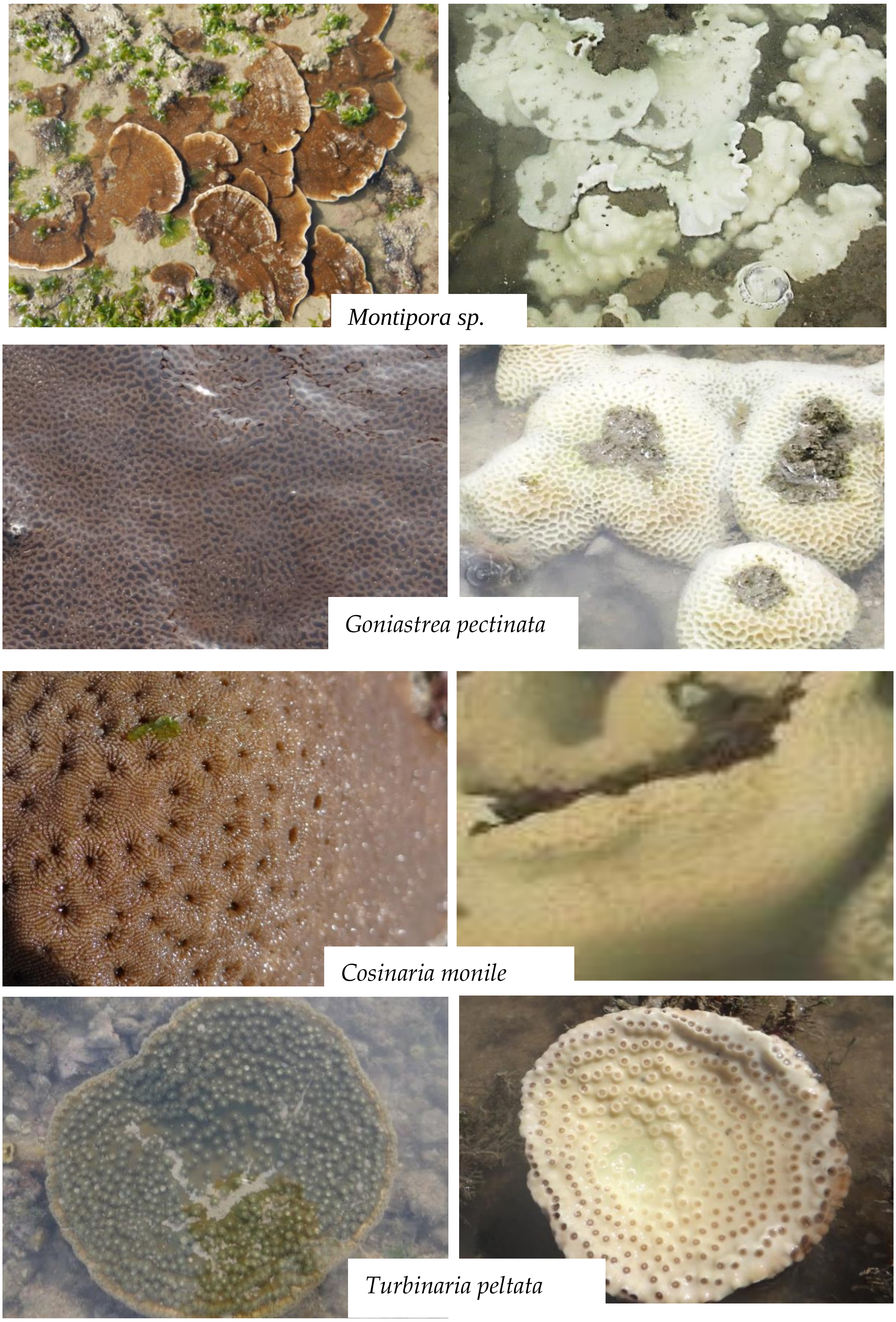


Plate 5.2 (c) Showing original and bleached condition of various coral species

Plate 5.3 Coral bleaching observed during 2010, 2013 and 2014-Reef view

Plate 5.4: Mass Coral bleaching recorded during summer 2010-Reef View

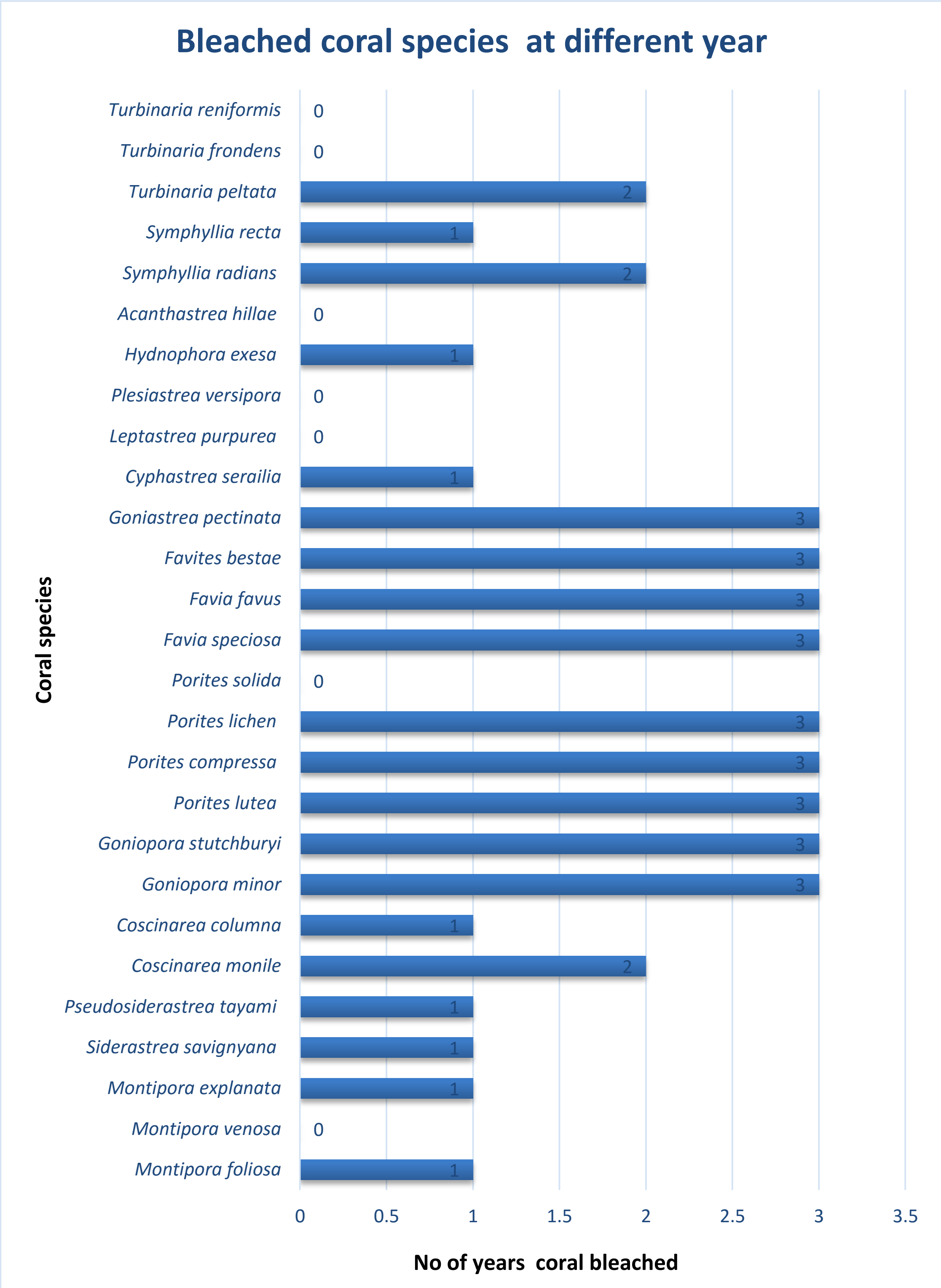


Figure 5.35: Showing bleaching frequency of each species at different year

Mass coral bleaching ranging from 25.8% to 41.3% was recorded from the coral reefs of the Palk bay during the month of April and May, 2010 (Ravindran *et al*., 2012). Other evidences of coral bleaching were recorded at Andaman and Nicobar Islands, which described the occurrence of mass coral bleaching, ranging from 37 to 70% at various sites during the month of April and May 2010. Such an extensive coral bleaching was induced by the elevated sea surface temperature at the respective sites (Krishnan *et al*., 2011). Evidences of mass coral bleaching were also reported from Lakshadweep during May and June, 2010 which revealed 76.5% bleached corals, 87.5% of sea anemones and 88% of giant clams (Kumar and Balasubramanian, 2012). Other coral reefs located at roughly the same latitude (22°39') as GoK, *i.e*., Persian Gulf (>34°C) and Red Sea also showed coral bleaching of 60-80% (Aug-Sept, 2010) and 14-74% (August, 2010) respectively (Riegl *et al.* 2011; Furby *et al.* 2013).

Arthur (1995) reported 1.2-1.4% of coral bleaching in the Gulf of Kachchh during summer months of Gujarat and concluded it to be a normal summer response of corals towards the summer temperature rise as the coral species of these latitudes are adapted to a wide range of temperature fluctuation at the intertidal regions. But during the summer of year 1998, he recorded an average of 11% coral bleaching in the Gulf of Kachchh resulted after El Nino Southern Oscillation and considered it as a higher level of coral bleaching than a normal summer response. He added that the elevated temperatures even below bleaching threshold can also substantially affect coral health by impairing growth and reproduction (Arthur, 2000). Ecologists of WTI have also recorded coral bleaching at Mithapur in the Gulf of Kachchh during the year 2010 (www.wti.org.in).

The apparent widespread coral bleaching episodes following its recovery might be triggered by a common and temporal factor of greater spatial magnitude. As well as the occurrence of the coral bleaching at different reef area also coincides with the high SST months of that area suggesting SST to be the major causal factor of the coral bleaching.

The coral reefs of the Gulf of Kachchh are one of the most stressed reefs of the country. In line with the present study, Vivekanandan *et al.*, (2009), predicted that the number of catastrophic events will increase from 0 during 2000–09 to 2 during 2050–59 in the Gulf of

Kachchh; and during 2080–89, eight of the 10 bleaching will be catastrophic events. Done *et al.*, (2003) in their studies have mentioned that that reef will not be able to sustain catastrophic events more than three times a decade. In the line of this statement Vivekanandan *et al.*, (2009) along with the Gulf of Kachchh, also predicted the vulnerability of the coral reefs of Lakshadweep, Andaman and Nicobar and the Gulf of Mannar wherein they mentioned that reef building corals may begin to decline between 2020 and 2040 and the reef building corals would lose dominance between 2030 and 2040 in the Lakshadweep region and between 2050 and 2060 in the Andaman and Nicobar regions and the Gulf of Mannar (Vivekanandan *et al.*, 2009).

Precisely, in their study they attempted to project the vulnerability of the corals of the Gulf of Kachchh. According to which, by 2030 to 2040, the corals may began to decline while by 2060 to 2070 the reef building corals will lose the dominance. However, in their study, they have made the predictions by analysing and projecting the future trends of the sea surface temperature whereas other factors such as increasing ocean water acidification, which would make it harder for the corals to form exoskeleton, in addition to that the factors such as UV-radiation, sedimentation, nutrient load, fluctuation in the physico-chemical properties of the ocean water have not been considered which also contribute in to the coral bleaching phenomenon. Moreover, McClanahan *et al.*, (2007) suggested that the rate of temperature rise is less important than SST background variation in predicting coral survival. They also found that bleaching was positively correlated with speed of water flow. Furthermore, studies have shown that ocean warming coincides with the rise in the sea level which results in frequent storms and El Ninos, which in turn affects the reefs and they are likely to experience greater coastal erosion, sedimentation and turbidity, which would accelerate their demise (Hodgson, 1999). In the changed scenarios of less or no coral cover, it is difficult to project the fate of organisms depending on the reef ecosystem and also the adjacent ecosystems that are supported by the reefs.

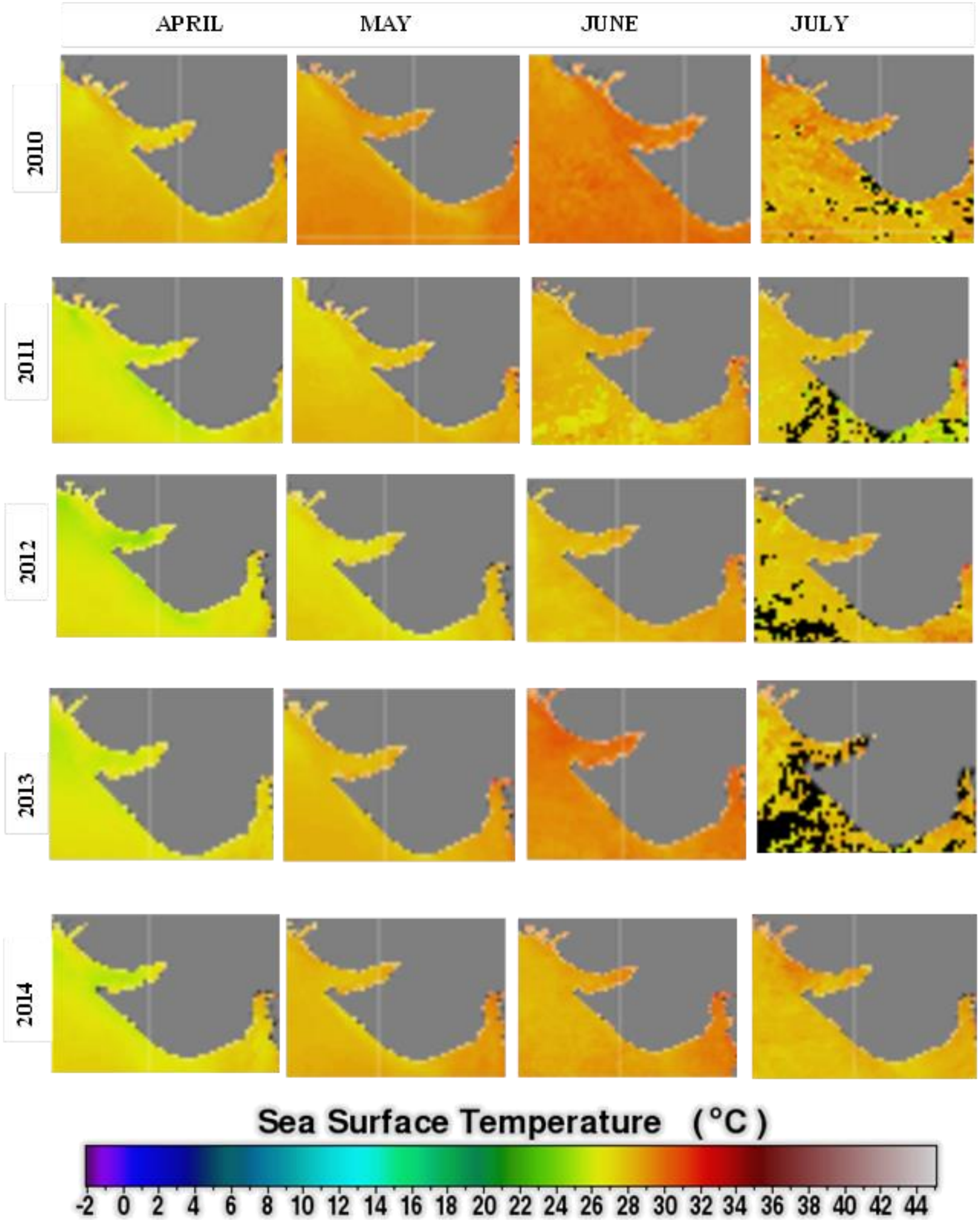


Plate 5.5: Comparisions of sea surface temperature from April to July for the year 2010 to 2014 (http://oceanmotion.org/html/resources/ssedv.htm)

Table 5.18 Coral species found bleached during the study

Sr.no	Coral species (Parasharya, 2012)	IUCN status	Corals Bleached-2010	Corals Bleached-2013	Corals Bleached-2014
Family: Acroporidae					
1.	*Montipora foliosa*	NT		✓	
2.	*Montipora venosa*	NT			
3.	*Montipora explanata*	DD	✓		
Family: Siderastreidae					
4.	*Siderastrea savignyana*	LC	✓		
5.	*Pseudosiderastrea tayami*	NT	✓		
6.	*Coscinarea monile*	LC	✓	✓	
7.	*Coscinarea columna*	LC	✓		
Family: Poritidae					
8.	*Goniopora minor*	NT	✓	✓	✓
9.	*Goniopora stutchburyi*	DD	✓	✓	✓
10.	*Porites lutea*	LC	✓	✓	✓
11.	*Porites compressa*	LC	✓	✓	✓
12.	*Porites lichen*	LC	✓	✓	✓
13.	*Porites solida*	LC			
Family: Faviidae					
14.	*Favia speciosa*	LC	✓	✓	✓
15.	*Favia favus*	LC	✓	✓	✓
16.	*Favites bestae*	NT	✓	✓	✓
17.	*Goniastrea pectinata*	LC	✓	✓	✓
18.	*Cyphastrea serailia*	LC	✓		
19.	*Leptastrea purpurea*	LC			
20.	*Plesiastrea versipora*	LC			
Family: Merulinidae					
21.	*Hydnophora exesa*	NT	✓	✓	
Family: Mussidae					
22.	*Acanthastrea hillae*	NT			
23.	*Symphyllia radians*	LC	✓	✓	
24.	*Symphyllia recta*	LC	✓		
Family: Dendrophyllidae					
25.	*Turbinaria peltata*	VU	✓	✓	
26.	*Turbinaria frondens*	LC			
27.	*Turbinaria reniformis*	VU			
Total			**19**	**13**	**9**

VU -Vulnerable, NT-Near Threatened, LC-Least Concerned, DD-Data deficiency

Coral bleaching consequences

Coral bleaching weakens the coral colonies against secondary stressors like algal overgrowth, diseases and reef organisms that bore into the skeleton and perforate the structure of the reef. The major causes or physiological changes include lower growth rates, reduced tissue biomass and community changes after even sublethal bleaching events that may reduce resilience of coral reefs to local stresses like overfishing, nutrient loading, and sedimentation. In 1998, when global mass coral bleaching was reported, the coral reefs that either had received high nutrient inputs or had low grazing fish populations tended to experience algal overgrowth showing weak potential to overcome the stress (Goreau *et al.*, 2000). Such an was also recorded in present study *i.e.*, the bleached coral colony showed lesser potential to remove the sedimentation settling on it. The sediments smother the polyp tissue and can damage the colony at moderate to severe rate. In the present study a large patch of *Porites lutea*. was recorded bleached and consequently unable to remove the thin layer of sediment. Additionally, other scleractinian species *i.e.*, *Porite compressa*, *Favia favus and Goniopora sp.* were also covered by sedimentation and damaged (corallites chocked up with sediment deposition).

In case of severe bleaching, the resilience of the reef also decreases causing shift in the patterns of coral diversity and resulting in reef community restructuring. In order to detect or trace changes of i) bleached coral reefs, ii) persistence of the changes, iii) magnitude of the changes as well as the iv) status of unbleached corals, a well-planned monitoring can serve as one of the best tool. The data generated from such information can provide us with pre-bleaching and post bleaching scenario of the coral reefs. Such a plan can also integrate the involvement of Policy makers, local organisations, universities and if possible local community. The comparisons of frequently and periodically collected data at the coral reef ecosystem can bring forth the trends of various consequences of the climate change with the course of time.

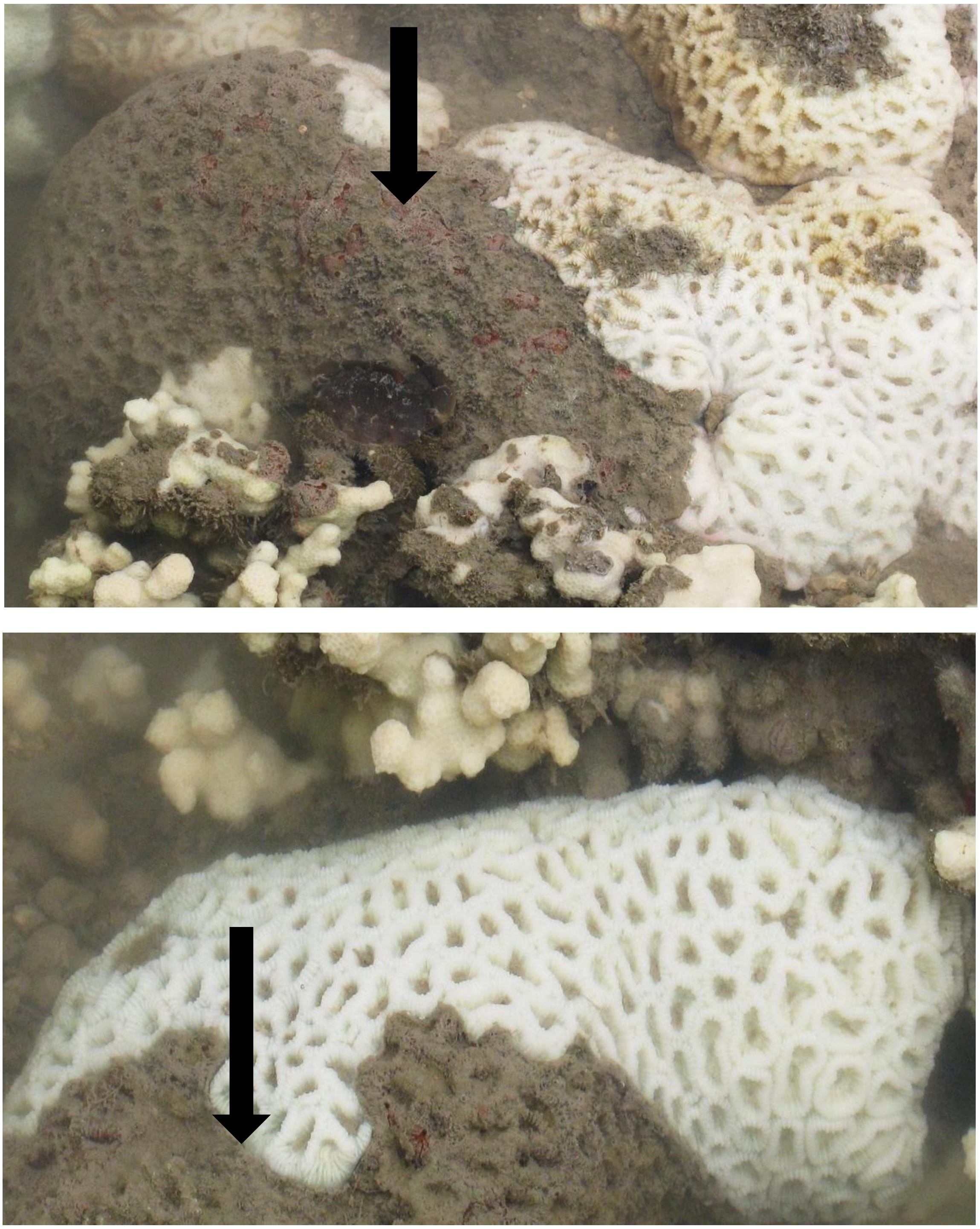


Plate:**5.6** Bleached coral colonies under sedimentation stress-*Favia favus*

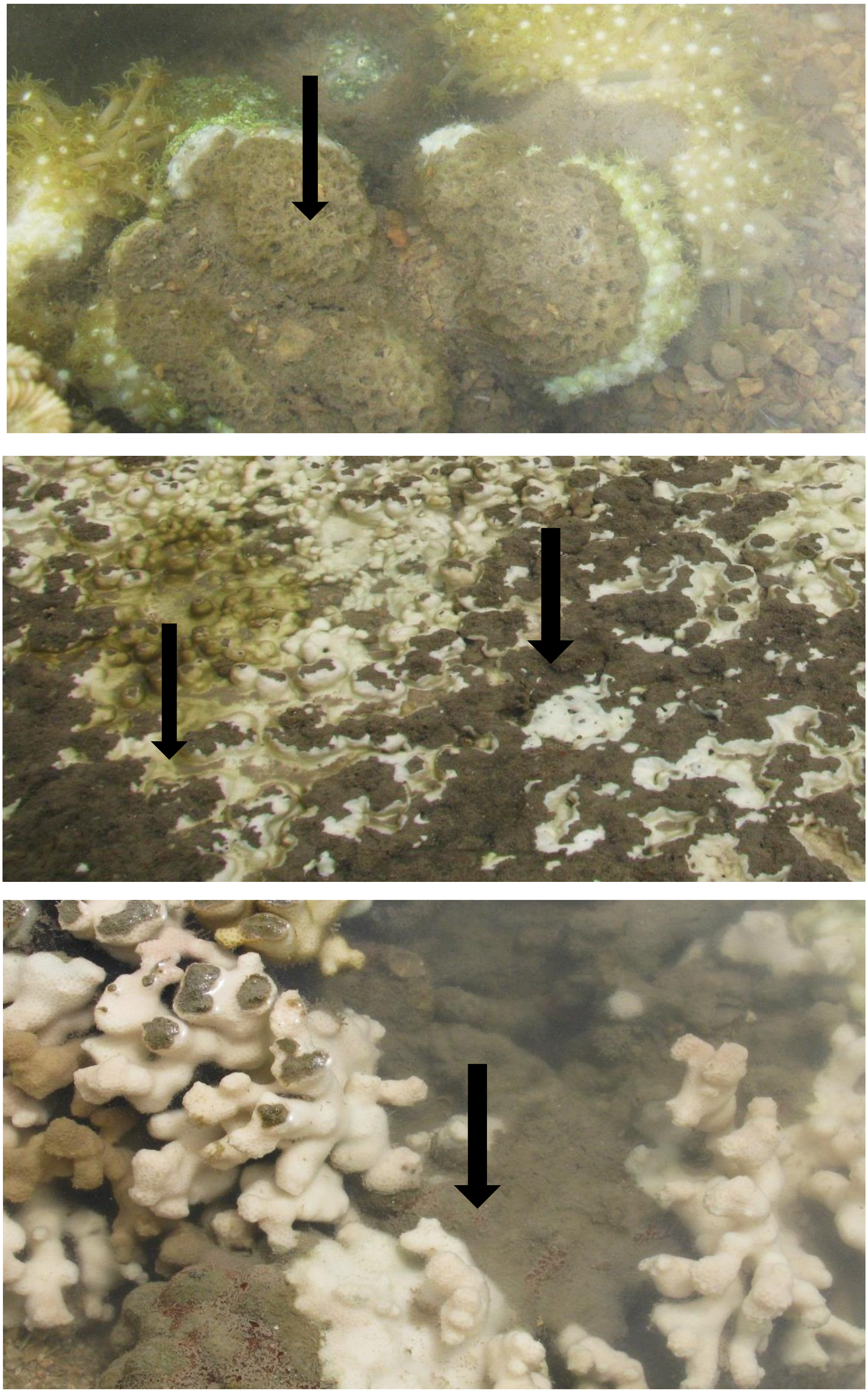


Plate: 5.7 Bleached coral colonies under sedimentation stress- *Goniopora sp, .Porites compressa.Porites lutea*

Additional to this, one more observation has been derived about the delayed recovery of genus *Porites* regarding coral bleaching and species specific response. The Frequency of occurrence for the *Porites sp.* was estimated to be 36% and 7.27% at Poshitra and Narara respectively. During the study, three species of the genus *Porites* were recorded namely *Porites lutea, P. compressa* and *P. lichen* distributed at various reef zones viz. reef flat, reef crest, reef slope, tidal pools and lagoons. All the species and growth forms of the *Porites* were recorded suffering from the delayed recovery (Figure 2). Nearly 30% of *Porites* colonies within transects were partially recovered from the mass coral bleaching event (Figure 3). However, other colonies belonging to rest of the genera had recovered completely and got their original pigmentation after the mass coral bleaching event of the year (Table 1). No other Anthozoans were observed in bleached condition.

The slower recovery of this scleractinian *Porites* can be explained by its unusual metabolic pathways. During the healthy state of corals, up to100% of daily metabolic requirement is fulfilled by photo-synthetically fixed carbon from zooxanthellae (Grottoli, *et al.,* 2006). Wherein, the excess is stored in the host as lipids at the concentrations of 10–40% of the total biomass (Grottoli, *et al.*, 2004) and represents a significant energy reserve in the corals (Harland, 1993) In bleached corals, decreased zooxanthellae densities or chlorophyll *a* levels result in decreased net photosynthesis (Grottoli, *et al.,* 2006). The photo-synthetically fixed carbon translocated to the host decreases that constrain the organism to rely on the stored lipid, carbohydrate or protein reserves to survive and recover.

However, unlike *Porites*, the bleached *Montipora capitata* maintains energy reserves by increasing heterotrophy which is the major difference of metabolism in *Porites* and other species (Grottoli, *et al.,* 2006). *Porites* does not increase heterotrophic inputs during stressed condition hence; the mode of nutrition makes it less resilient against bleaching events compare to other species (Grottoli, *et al.*, 2006). In addition to this *Porites* shows a different pathway for lipid metabolism, *i.e.*, *Porites* completely, rather than sequentially, metabolizes storage lipids triacylglycerol (TG), wax esters (WE) and phospholipid (PL) affected after bleaching which results in delayed recovery(Grottoli, *et al.,* 2006). The bleached *Porites* shows loss of wax esters impairing egg and mucus production. This loss consequently decreases reproductive output and potential of sediment removal from colony. This is not desirable for any reef species to maintain the long term survival of a coral species or a reef.