FAVIID DIVERSITY STUDIES

The relative abundance, Frequency of sightings and diversity of Faviids at Narara and Poshitra reefs and their comparison with the help of single factor ANOVA, various diversity indices and Bray Curtis similarity distribution have been performed.

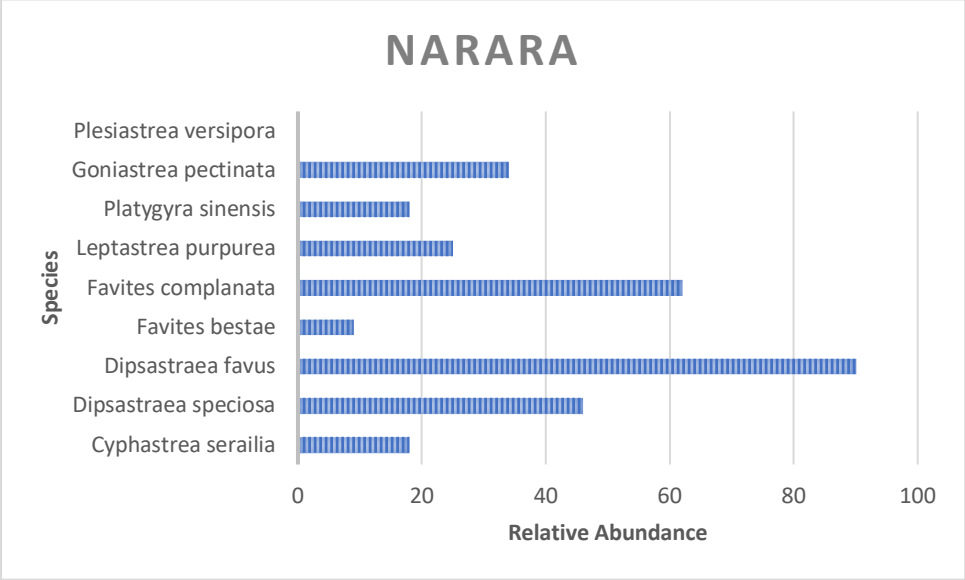


FIGURE 1 RELATIVE ABUNDANCE OF FAVIIDS AT NARARA

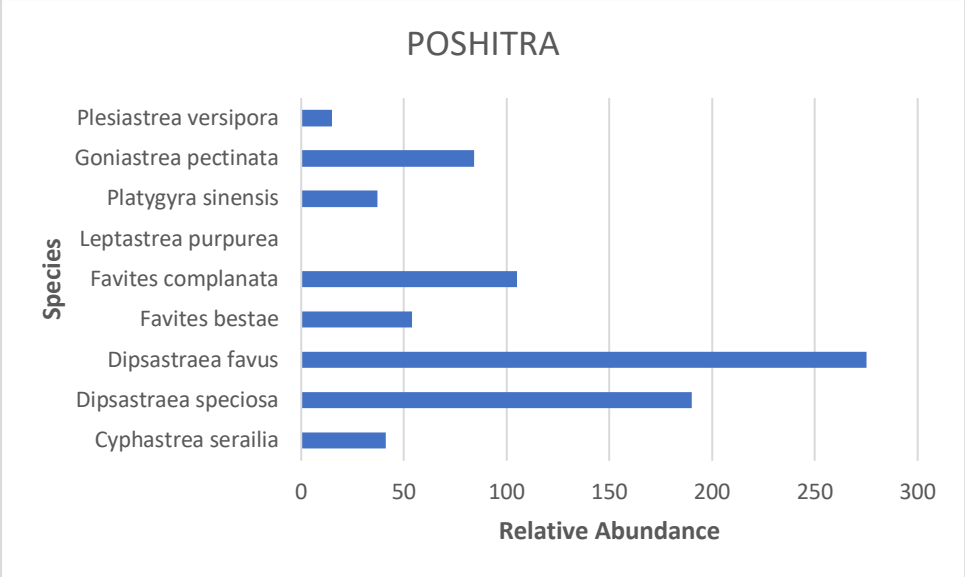


FIGURE 2 RELATIVE ABUNDANCE OF FAVIIDS AT POSHITRA

All together 9 species of faviids were recorded at the two coastal reefs studied with 7 species shared while one each differed (Annexure 1). The most abundant species here were *Dipsastraea favus* followed by *Favites complanata* and *Dipsastraea speciosa* whereas the least found was *Favites bestae* (Fig.11). *Plesiastrea versipora* which had marked its presence in Poshitra was not recorded here.

The Poshitra reef (Fig. 12) showed almost same composition of Faviid species as observed at Narara. However, their population status differed. The additional species observed here was *Plesiastrea versipora* with minimum occurrence while *Leptastrea purpurea* was not observed. The most abundant Faviid found in this region was also *Dipsastraea favus* but followed by *Dipsastraea speciosa* and then *Favites complanata*. Both the study sites had *Favites complanata* as common species that was found to be reasonably abundant. Most of the encountered individuals of the *Cyphastrea serailia* were found to be isolated from the other species of Scleractinians as well. *Platygyra sinenses* shared nearly the same status of population with *Favites bestae* at both the study sites.

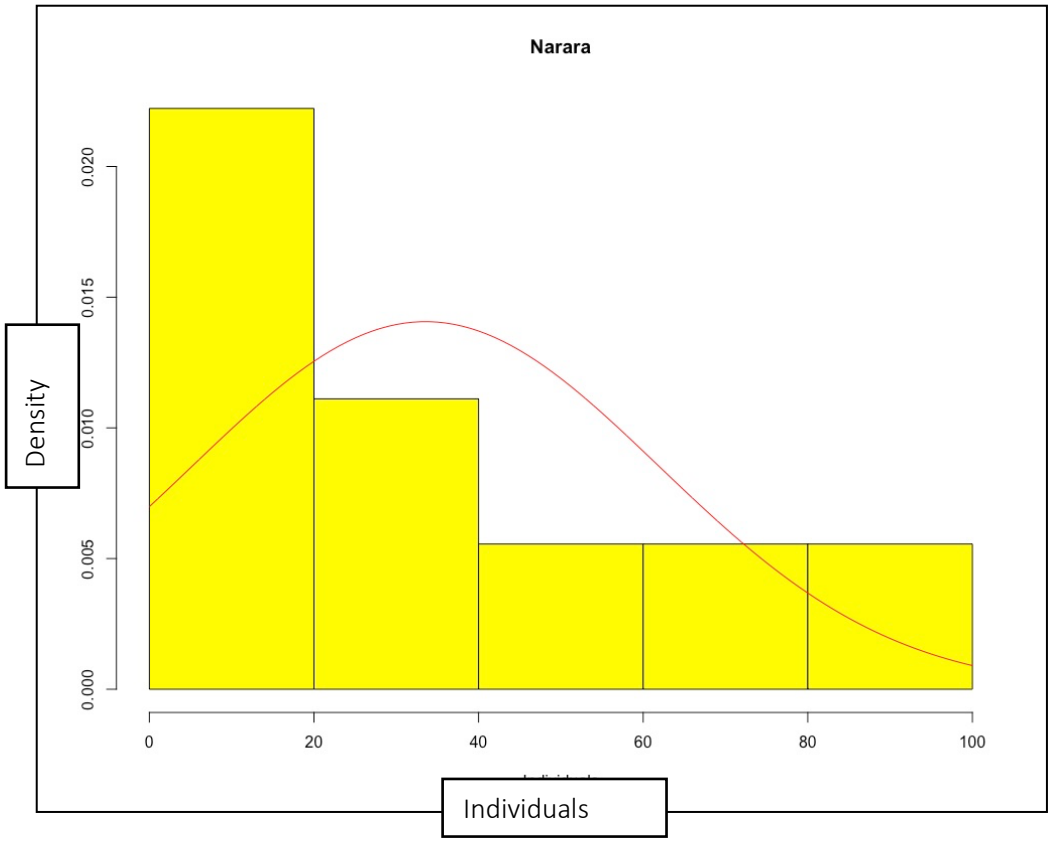


FIGURE 3 FREQUENCY OF SIGHTINGS OF FAVIIDS AT NARARA REEF

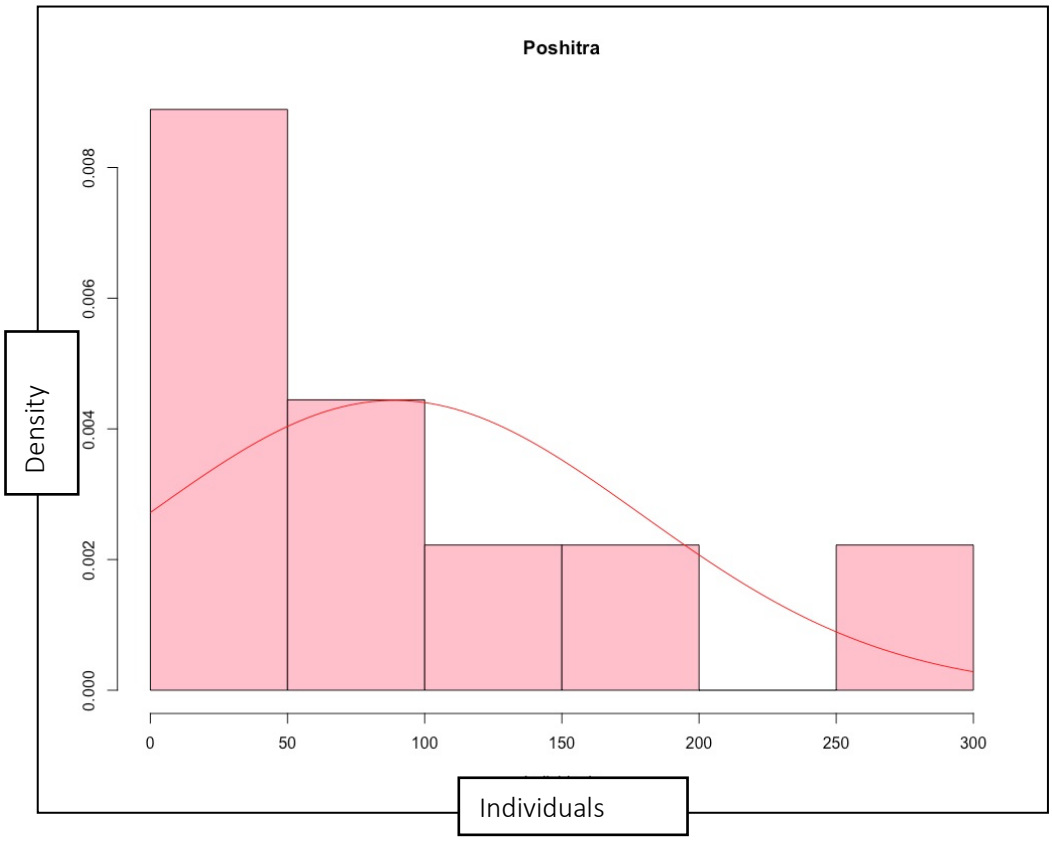


FIGURE 4 FREQUENCY OF SIGHTINGS OF FAVIIDS AT POSHITRA REEF

The frequency histograms plotted to find out the class intervals and the frequency of occurrence of species at both the reefs are given in figures 3.3 and 3.4 respectively. Narara reef (Fig. 13) gave 5 class intervals showing the maximum range of 100. Their mid values were 10,30,50,70 and 90. The species encountered in the range of 0- 20 were with frequency rate of 0.025 which was the highest frequency rate in the class intervals. The second highest was found in the range of 20-40 class interval with the frequency rate of 0.011. Whereas, the other three intervals viz. 40-60, 60-80 and 80-100 were of low frequency rate at 0.005 in the number of individuals sighted in Narara coastal reef.

The Poshitra reef (Fig. 14) gave total six class intervals as 50, 100, 150, 200, 250 and 300. These intervals had mid values ranging from 25, 75, 125, 175, 225 and 275. The highest frequency rate of 0.008 was in class interval of 0-50 while the second highest frequency rate of 0.004 was found at class interval of 50-100. Rest all intervals were found between 100-150, 150-200 and 250-300 at frequency rate of 0.002. However, the class interval 200-250 not represented i.e, no individuals were found within this rate of encounter. The highest value of *Heteractis malu* was removed as it was an outlier in the frequency histogram.

Both the histograms showed the un-even distribution of Faviids at the respective reefs. No normal distribution is seen here as the values were positively skewed. A trend line of mesokurtosis was obtained for Narara reef and Platykurtosis for Poshitra reef.

TABLE 1 TWO-SAMPLE F-TEST PERFORMED TO FIND OUT VARIANCE OF TOTAL FAVIIDS OBSERVED AT NARARA AND POSHITRA

	POSHITRA	**NARARA**
Mean	89	33.55
Variance	8088.5	804.52
Observations	9	9
df	8	8
F	10.053	
P(F<=f) one-tail	0.001	
F Critical one-tail	3.44	

TABLE 2 A COMPARISON OF FAVIID DIVERSITY OF NARARA AND POSHITRA REEFS USING SINGLE FACTOR ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13833.39	1	13833.39	3.111	0.096	4.493
Within Groups	71144.22	16	4446.514			
Total	84977.61	17				

TABLE 3 DESCRIPTIVE STATISTICS OF NARARA AND POSHITRA REEFS

	NARARA	**POSHITRA**
Mean	33.55	89
Standard Error	9.45	29.97
Median	25	54
Mode	18	NIL
Standard Deviation	28.36	89.93
Sample Variance	804.52	8088.5
Kurtosis	0.63	1.19
Skewness	1.01	1.33
Range	90	275
Minimum	0	0
Maximum	90	275
Sum	302	801
Count	9	9

The two reefs in Southern Gulf of Kachchh, Gujarat i.e. Narara and Poshitra, sampled and studied for Faviid diversity and ecology showed presence of significantly different number of total Faviids encountered. The variance for Narara was 804.5 and that Poshitra was 8088.5 showing the farthest of population distributed in the respective reefs. The F-test (Table 1) was applied to the variances between the two reefs. Here f-value between the two reefs was 10.05 that is greater than F crit one tail 3.44 stating that the variances from the two populations are unequal.

As Table 1 shows that the populations of two reefs vary considerably the populations of individual species were checked whether they have any relation to the respective reefs or not by applying Analysis of Variance (ANOVA Single factor) (Table 2). The significance value obtained was 0.096. The results showed most of the population included same species that were found on the two reefs.

The descriptive statistics of Narara and Poshitra reefs with reference to faviid diversity is given in Table 3. The Narara reef had counts in the range between minimum 0 and maximum 90 with Mean 33.55. Whereas, the Poshitra reef also had minimum zero but maximum 275 counts with Mean 89. The sum of the total individuals found at Narara reef was 302 and Poshitra reef 801. The standard deviation of the both the reefs differed in terms population because the number of individuals found on both the sites varied remarkably giving an account of SD $\pm$ 28.32 for Narara and SD $\pm$ 89.93 for Poshitra. Both the reefs showed positive skewness in terms of individuals encountered with Narara at +1.01 and Poshitra +1.33 skewness. Both the reefs showed platykurtic distribution having no outliers in the population (as *Heteractis malu* was already removed).

TABLE 4 DIVERSITY INDICES FOR FAVIIDS OF TWO REEFS

	NARARA	POSHITRA
Taxa_S	8	8
Individuals	302	801
Dominance_D	0.18	0.21
Simpson_1-D	0.81	0.78
Shannon_H	1.86	1.76
Evenness_e^H/S	0.80	0.72
Margalef	1.22	1.04

The Table 4 shows the diversity indices of both reefs. The total Taxa found at both the sites are 8 species each. The total individuals encountered at Narara were 302 whereas at Poshitra 801. The Dominance D index was high for Poshitra reef at 0.21 whereas low 0.18 for Narara reef. However, the Evenness index was higher for Narara (0.80) among the two reefs, whereas it was 0.7 for Poshitra. The Margalef's index was also higher for Narara (1.22) as compared to Poshitra (1.04).

TABLE 5 BRAY CURTIS SIMILARITY DISTRIBUTION AND POPULATION INDICES OF FAVIIDAE

	Cyphastrea serailia	***Dipsastraea speciosa***	***Dipsastraea favus***	***Favites bestae***	***Favites complanata***	***Leptastrea purpuria***	***Platygyra sinesis***	***Goniastrea pectinata***	***Plesiastrea versipora***
Cyphastrea serailia	1								
Dipsastraea speciosa	0.4	1							
Dipsastraea favus	0.27 #	**0.78##**	1						
Favites bestae	**0.81 ##**	0.42	0.29#	1					
Favites complanata	0.52	**0.74##**	0.62	0.5	1				
Leptastrea purpuria	0.42	0.19#	0.12#	0.20#	0.26#	1			
Platygyra sinesis	**0.96##**	0.37#	0.26#	**0.77##**	0.49	0.45	1		
Goniastrea pectinata	0.66	0.66	0.48	0.69	**0.82##**	0.34#	0.63	1	
Plesiastrea versipora	0.40	0.11#	0.07#	0.38#	0.16#	0	0.42	0.22#	1

##– Farthest, #- Nearest

The Bray Curtis index (Table 5) was performed to find out the similarity of the species in terms of population status at Narara and Poshitra coastal reefs. In the graph, *Cyphastrea serailia* was distant at 0.4 from *Dipsastraea speciosa* , 0.278 from *Dipsastraea favus ,* 0.819 from *Favites bestae*, 0.522 from *Favites complanata*, 0.428 from *Leptastrea purpurea*, 0.964 from *Platygyra sinenses*, 0.666 from *Goniastrea pectinata* and 0.405 from *Plesiastrea versipora*. The *Dipsastraea speciosa* was distant at 0.785 from *Dipsastraea favus* , 0.421 from *Favites bestae,* 0.749 from *Favites complanata*, 0.191 from *Leptastrea purpurea,* 0.378 from *Platygyra sinenses*, 0.666 from *Goniastrea pectinata* and 0.119 from *Plesiastrea versipora*. The *Dipsastraea favus* was distant at 0.294 at *Favites bestae*, 0.627 from *Favites complanata*, 0.128 from *Leptastrea purpurea,* 0.261 from *Platygyra sinenses*, 0.488 from *Goniastrea pectinata* and 0.078 from *Plesiastrea versipora*. The *Favites bestae* was distant at 0.547 from *Favites complanata*, 0.204 from *Leptastrea purpurea*, 0.779 from *Platygyra sinenses*, 0.696 from *Goniastrea pectinata* and 0.384 from *Plesiastrea versipora*. The *Favites complanata* was distant at 0.260 from *Leptastrea purpurea,* 0.495 from *Platygyra sinenses*, 0.828 from *Goniastrea pectinata* and 0.164 from *Plesiastrea versipora*. The *Leptastrea purpurea* was distant at 0.45 from *Platygyra sinenses*, 0.349 from *Goniastrea pectinata* and 0 from *Plesiastrea versipora*. The *Platygyra sinenses* was distant at 0.635 from *Goniastrea pectinata* and 0.428 from *Plesiastrea versipora*. Whereas *Goniastrea pectinata* was distant at 0.225 at *Plesiastrea versipora.*

ASSOCIATED FAUNA - MACROBENTHOS

The macrobenthic fauna associated with the Family Faviidae was also studied. This enabled to evaluate the population density of the fauna associated with the Faviidae at both the reefs. The associated fauna was evaluated with reference to total number of Species and their individuals encountered (Table 6), difference in the Diversity indices (Table 7) and in the terms of general categories of the macrobenthic fauna, viz. Poriferans,

Zoantharians, Actiniaria, Scleractinia, Crustacea, Gastropods, Nudibranchs, Echinoderms and Pisces (Figures 15-32). The abundance values were calculated for each group of macrobenthic fauna for Narara and Poshitra coastal reefs.

TABLE 6 TOTAL NUMBER OF SPECIES AND THEIR INDIVIDUALS ENCOUNTERED AT NARARA AND POSHITRA COASTAL REEFS

Phylum	**NARARA**		**POSHITRA**	
	Species	Individuals	Species	Individuals
Porifera	6	327	7	203
Cnidaria	29	1351	48	8220*
Annelida	3	57	2	18
Platyhelminths	4	7	1	1
Crustaceans	11	236	12	214
Mollusca	23	1059	28	636
Echinodermata	5	436	4	337
Pisces	9	180	6	37
Total	90	3653	112	9666

The total number of species and their individuals encountered during the study at the Narara and Poshitra coastal reefs are given in Table 6. Six Poriferan species were encountered at Narara reef with total count 327 while 7 species were encountered at Poshitra reef with total 203 individuals. The Cnidarian diversity at Narara reef was 29 species with total 1351 individuals counted while that for Poshitra reef was 48 species and 8220 individuals counted. The list of Annelids observed in Narara coastal reef

comprised 3 species and 57 individuals whereas in Poshitra 2 species with 18 individuals were noted. The number of species of Platyhelminths encountered at Narara reef was 4 with only 7 individuals while at Poshitra only 1 species with only one individual was recorded. The next group Crustacea was represented by 11 species with 236 individuals in Narara reef while 12 species and 214 individuals at Poshitra reef. Along with Crustaceans, Molluscs that included octopus and many gastropods were also studied. The Molluscan diversity at Narara was 23 species with 1059 individuals and at Poshitra 28 species and 636 individuals. Echinoderm were represented by 5 species and 436 sightings at Narara. At Poshitra though the number of species recorded was higher to 8, the total individuals encountered were only 337. The fish diversity recorded at Narara was 9 and total 180 times encountered whereas at Poshitra it was only 6 with 37 encounters. Thus, the total number of species encountered in Narara was 90 with total 3653 individuals, whereas at Poshitra 112 species with 9666 individuals.

TABLE 7 DIFFERENCE IN THE DIVERSITY INDICES AT NARARA AND POSHITRA REEFS

	Narara	Poshitra	Significance
Taxa	56.66 + 7.59	68.5 + 10.29	**
Individuals	289.41 + 68.19	801.16 + 619.46	*
Dominance	0.03 + 0.005	0.16 + 0.11	**
Simpson	0.96 + 0.005	0.83 + 0.11	**
Shannon	3.67 + 0.15	2.95 + 0.47	***
Evenness	0.70 + 0.06	0.32 + 0.14	****
Margalef	9.87 + 1.25	10.36 + 0.89	ns

(students's t test Two tail p= 0.3)

*P<0.1, ** P< 0.01 *** P< 0.001

The diversity indices for each visit at Narara and Poshitra (Table 7) were calculated and pooled to find out mean and apply t-test to find out the differences. The species mean was 56.66 $\pm$7.59 for Narara and 68.5 $\pm$10.29 for Poshitra with significance at **. The mean for individuals observed was 289.41 $\pm$68.19 for Narara and 801.16 +619.46 for Poshitra with significance at *. The dominance was 0.03 +0.005 for Narara and 0.16 +0.11 for Poshitra with significance at **. The Simpson index was 0.96 +0.005 for Narara and 0.83 +0.11 for Poshitra significance at **. The Shannon H was 3.67 +0.15 for Narara and 2.95 +0.47 for Poshitra with Significance at ***. The Evenness was 0.70 +0.06 for Narara and 0.32 +0.14 for Poshitra. Significance at ****, while the Margalef index was 9,87 +1.12 for Narara and 10.36 +0.89 at Poshitra was not significant.

PORIFERA:

At Narara total six species of poriferan were noted (Table 8 Fig. 15). *Haliclona implexiformes* was found to be most abundant followed by *Cliothosa delitrix* and *Haliclona sp.1* while *Galiodes* sp. was found in least numbers. *Haliclona* sp.1 an unidentified species was found to be most abundant at Poshitra coastal reef followed by *Cliothosa deltrix* and *Haliclona implexiformes*, whereas *Callyspongia sp*. occurred in lowest number. The diversity of Poriferans at Poshitra comprised of total seven species (Fig. 16).

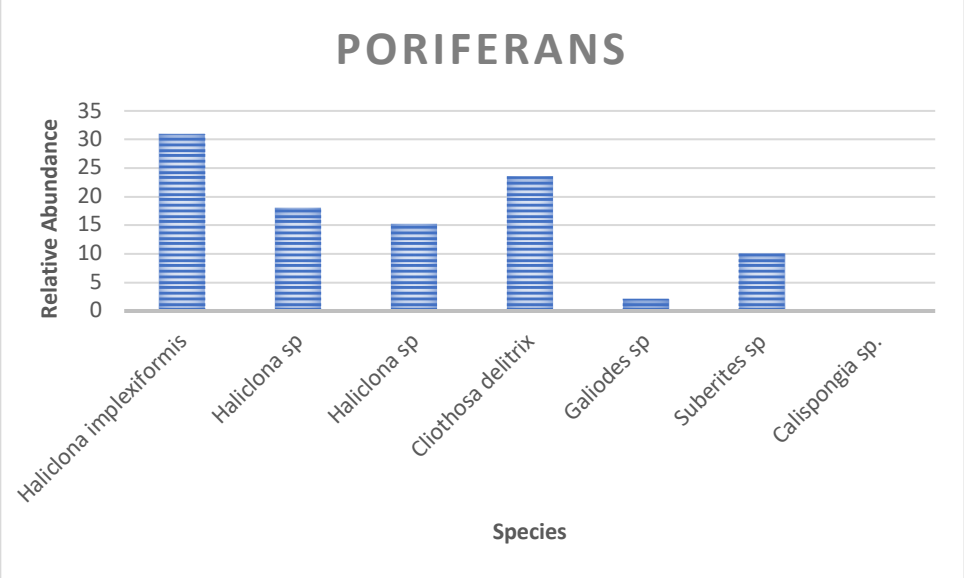


FIGURE 5 RELATIVE ABUNDANCE OF PORIFERANS AT NARARA

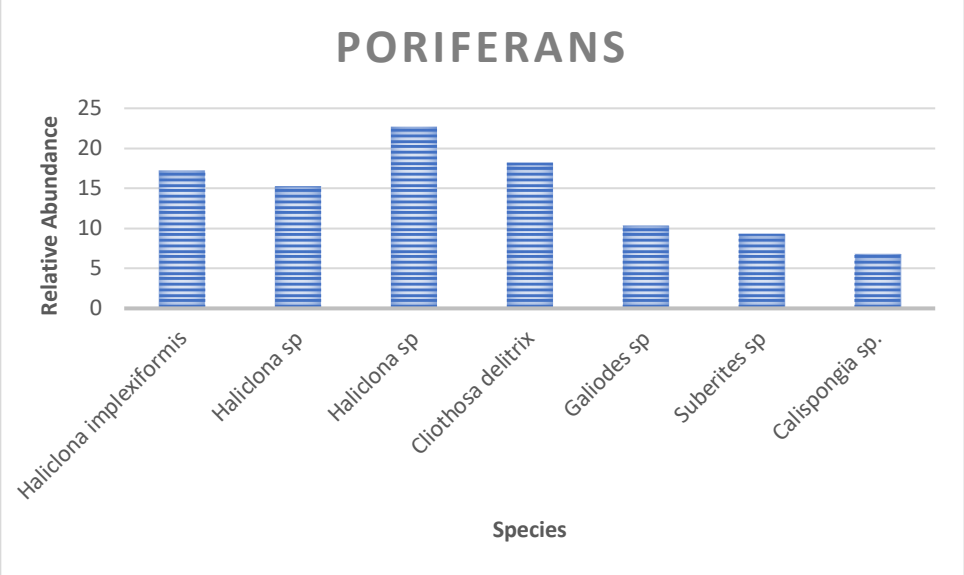


FIGURE 6 RELATIVE ABUNDANCE OF PORIFERA AT POSHITRA

TABLE 8 ABUNDANCE OF PORIFERANS AT NARARA AND POSHITRA COASTAL REEFS

Scientific Name	Narara	Poshitra
	Porifera	
Haliclona implexiformis	30.88	17.24
Haliclona sp.	18.04	15.27
Haliclona sp.	15.29	22.66
Cliothosa delitrix	23.54	18.22
Galiodes sp.	2.14	10.34
Suberites sp.	10.09	9.35
Callyspongia sp.	0	6.89

ZOANTHARIANS:

The diversity of Zoantharians at Narara (Fig. 17 Table 9) was very low compared to that of Poshitra (Fig. 18, Table 9). Only two species *Palythoa mutuki* and *Zoanthus sansabaricus* were found to be present at this reef. Both the species were almost equally common and abundant. However, at Poshitra coastal reef total six species of Zoantharians were recorded. *Palythoa tuberculosa* was found to be most abundant in this region followed by *Zoanthus sansabaricus* and *Palythoa mutukii*. The least found zoanthid was *Zoanthus sp.* The Zoantharians present at Poshitra showed higher abundance values than those present at Narara.

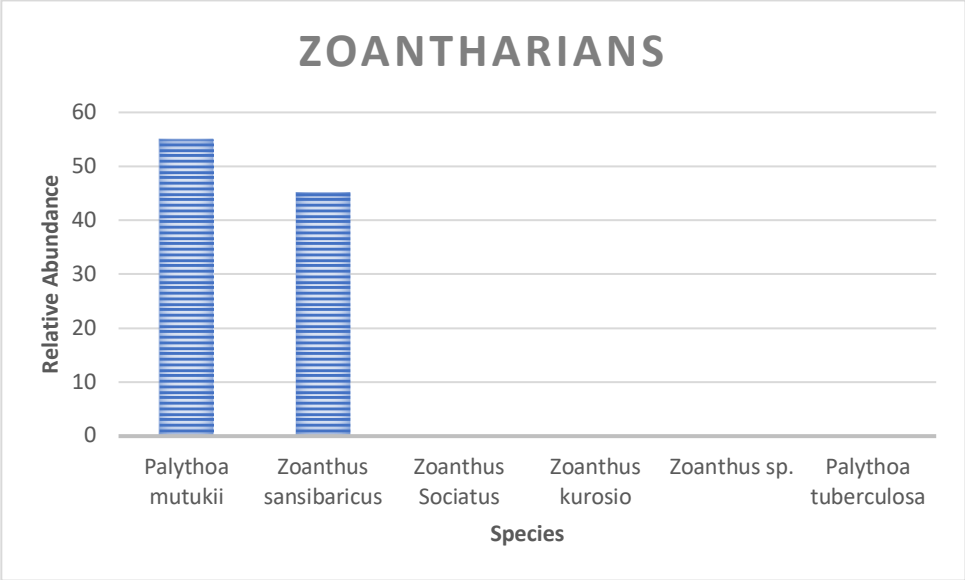


FIGURE 7 RELATIVE ABUNDANCE OF ZOANTHARIANS AT NARARA

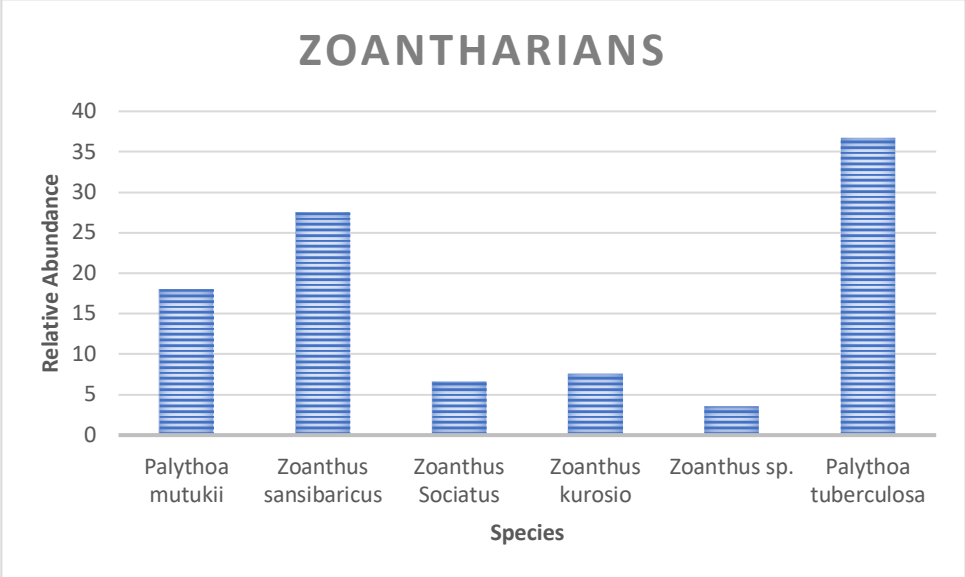


FIGURE 8 RELATIVE ABUNDANCE OF ZOANTHID AT POSHITRA

TABLE 9 ABUNDANCE OF ZOANATHIDS AT NARARA AND POSHITRA COASTAL REEFS

Zoantharians

Scientific Name	Narara	Poshitra
Palythoa mutukii	54.92	18
Zoanthus sansibaricus	45.07	27.48
Zoanthus Sociatus	0	6.63
Zoanthus kuroshio	0	7.58
Zoanthus sp.	0	3.55
Palythoa tuberculosa	0	36.72

ACTINIARIA

Total six species of Actiniarians were noted for Narara coastal reef (Table 10 Fig. 19) Here, abundance of *Heteractis malu* was highest followed by *Stichodactyla gigantea* and *Stichodactyla haddoni*. The least individuals of *Cerianthus sp* were observed. At Poshitra reef (Fig. 20) total twelve species were recorded. *Heteractis malu* was dominating this region in terms of numbers compared to other Actiniarians as 1400+ individuals were recorded in one of the twelve visits. The second most abundant Actiniarian was *Aiptasia pulchella* followed by *Heteractis crispa*. The least individuals were observed for *Cerianthus* sp., *Heteractis crispa* and *Phymanthus* sp.

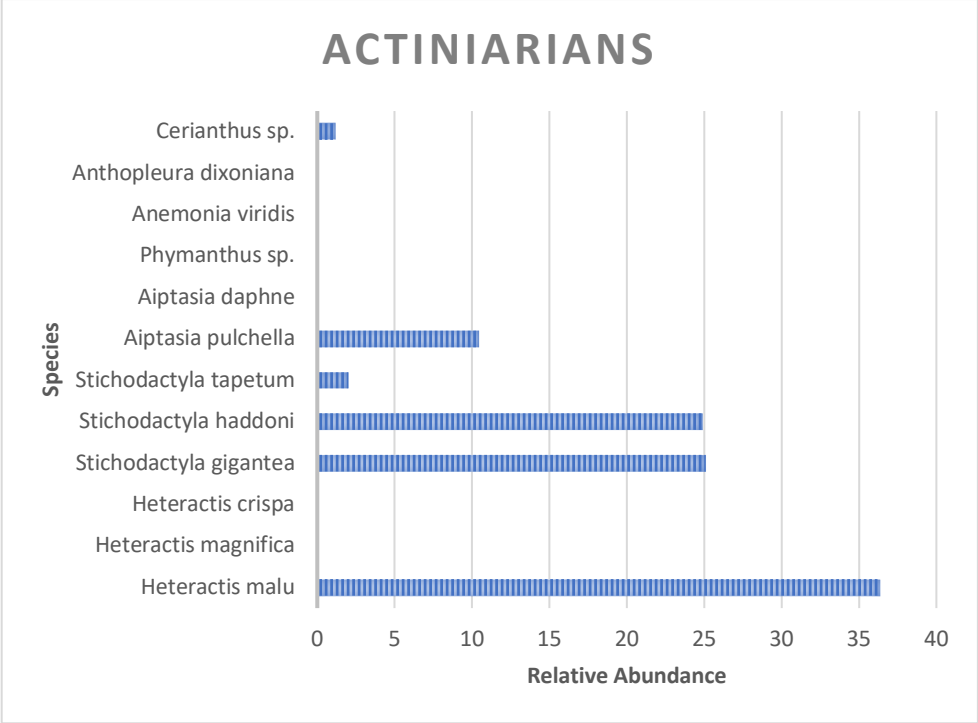


FIGURE 9 RELATIVE ABUNDANCE OF ACTINIARIA AT NARARA

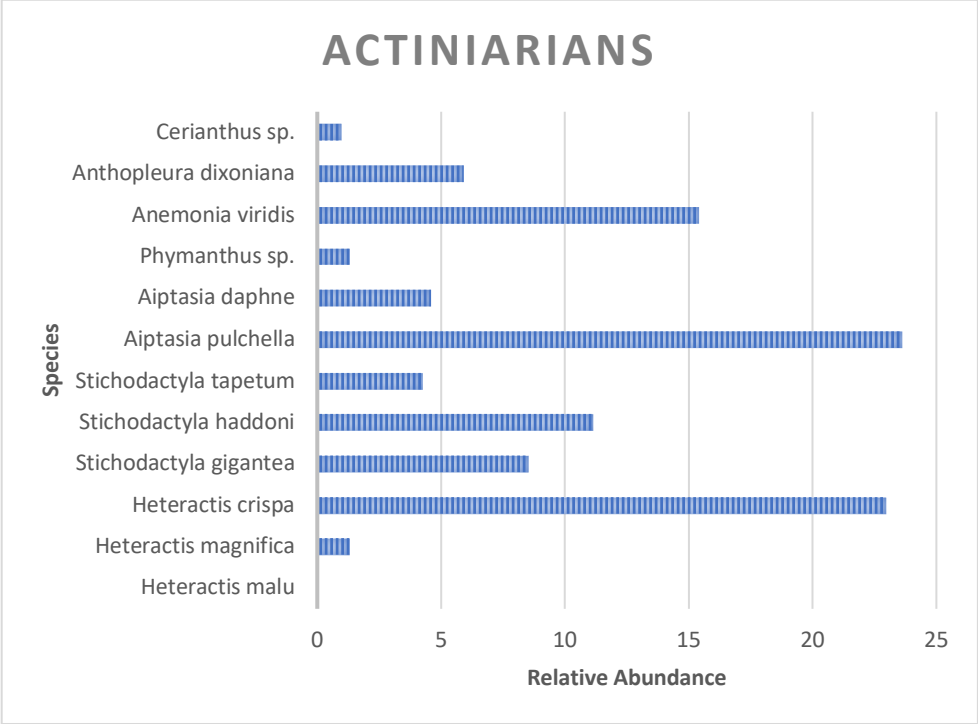


FIGURE 10 RELATIVE ABUNDANCE OF ACTINIARIA AT POSHITRA

TABLE 10 ABUNDANCE OF ACTINIARIA AT NARARA AND POSHITRA COASTAL REEFS

Actiniaria		
Scientific Name	**Narara**	**Poshitra**
Heteractis malu	36.34	0
Heteractis magnifica	0	1.31
Heteractis crispa	0	22.95
Stichodactyla gigantea	25.10	8.52
Stichodactyla haddoni	24.89	11.14
Stichodactyla tapetum	2	4.26
Aiptasia pulchella	10.44	23.60
Aiptasia daphne	0	4.59
Phymanthus sp.	0	1.31
Anemonia viridis	0	15.40
Anthopleura dixoniana	0	5.90
Cerianthus sp.	1.20	0.98

SCLERACTINIANS/ALCYONARIANS

The Scleractinian diversity was found to be the most dynamic in terms of populations present at both Narara (Fig. 21) and Poshitra (Fig.22) coastal reefs as soft corals that resemble general category of Scleractinia associated with the Faviidae were also taken into account (Table 11). Thus, the population and abundance of Scleractinia other than Faviidae were high. However, soft corals were not encountered at Narara coastal reef, nonetheless they were encountered at Poshitra coastal reef (Fig. 22). At Narara reef total twenty-one species marked their presence. The *Dipsastraea favus* was found to be most abundant followed by the *Porites lutea* and *Porites lichen.* Other species present were *Favites complanata,*

Siderastrea savignyana, Lobophyllia sp.1, Dipsastraea speciosa , Montipora foliosa, Goniopora pedunculata, Goniopora nigra, Goniastrea pectinata, Lobophyllia radians, Leptastrea purpurea, Paracyathus stokesii, Platygyra sinenses, Homophyllia bowerbanki, Cyphastrea serailia. The least abundant species found were *Montipora sp., Pseudosiderastrea tayamii and Favites bestae.*

At Poshitra reef total twenty-eight species of scleractinians were present. Here *Duncanopsammia peltata* was most abundant followed by the *Goniopora pedunculata* and *Dipsastraea favus*. Various other scleractinian present were *Goniopora nig*ra, *Porites lutea, Dipsastraea speciosa , Porites lichen, Porites solida, Favites complanata, Goniastrea pectinatata, Turbinaria reniformes, Lobophyllia sp.1, Lobophyllia radians, Porites compressa, Montipora sp., Cyphastrea serailia, Homophyllia bowerbanki, Platygyra sinensis, Sinularia sp*. The species with lower abundance were *Tubastrea aurea Dendronephtheya sp*., and *Plesiastrea versipora*. Most species under family Poritidae were observed in this region. Though present, the soft corals were found in least numbers in Poshitra. However, it tended to vary at each visit made on the reef.

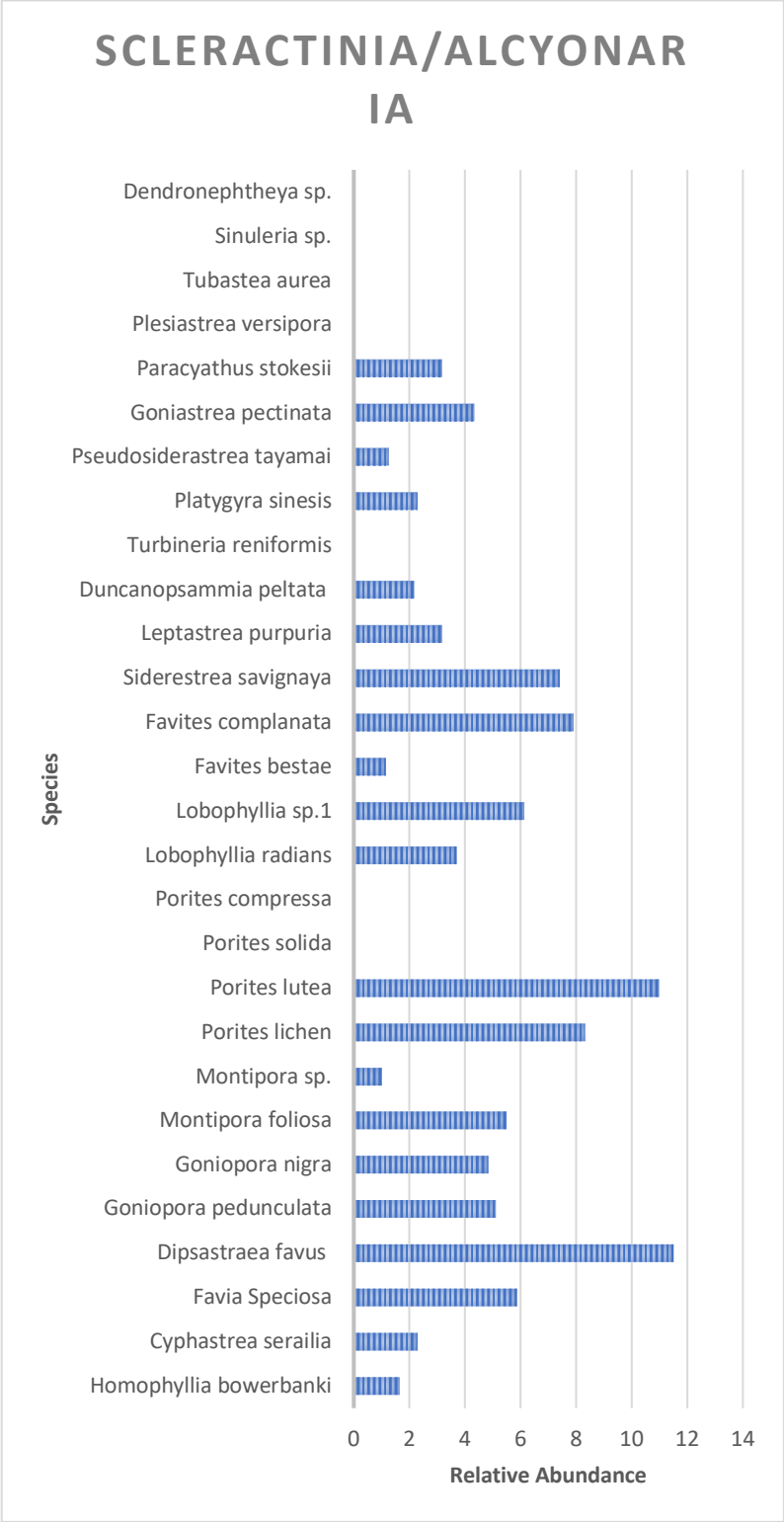


FIGURE 11 RELATIVE ABUNDANCE OF SCLERACTINIA/ALCYONARIA AT NARARA

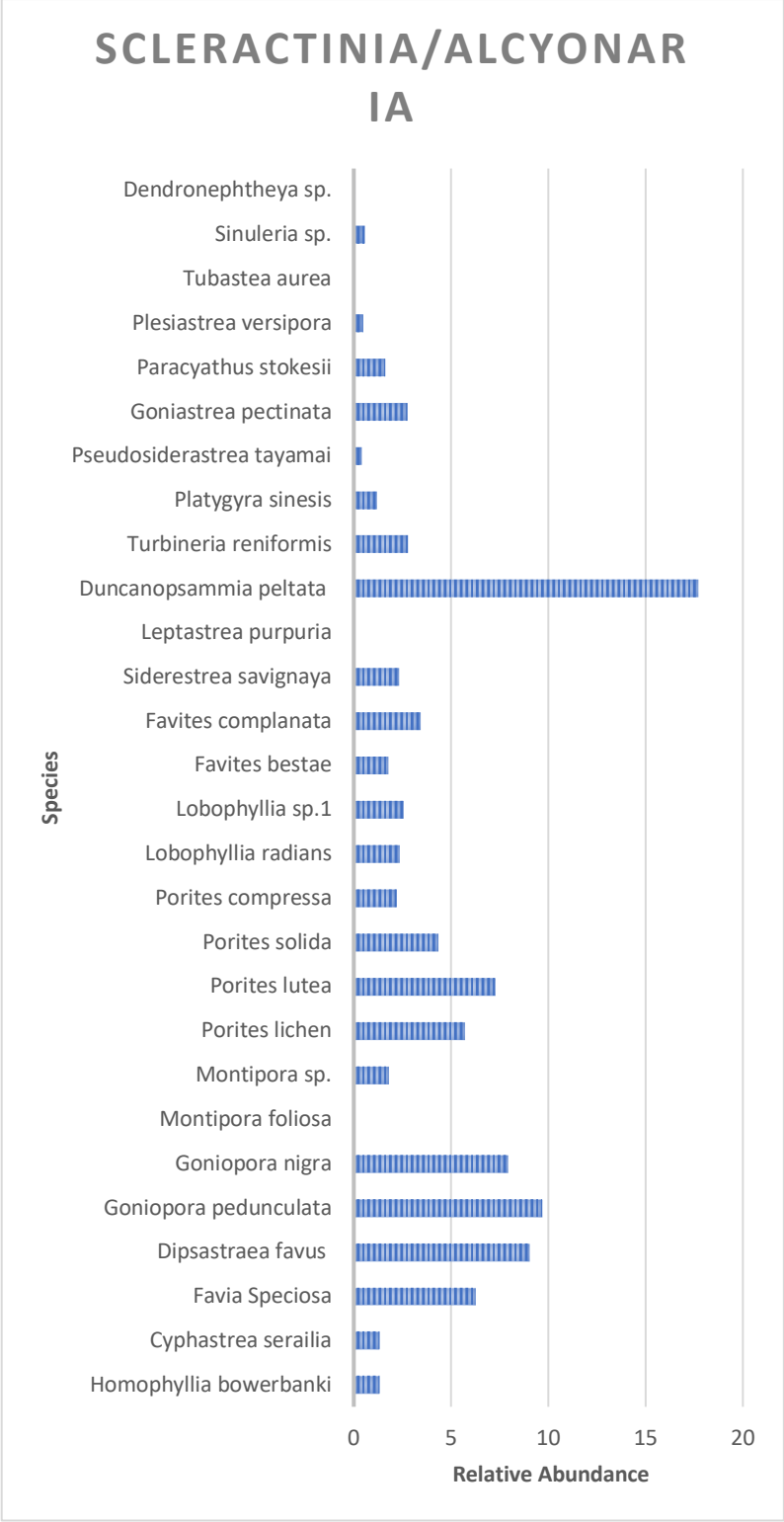


FIGURE 12 RELATIVE ABUNDANCE OF SCLERACTINIA/ALCYONARIA AT POSHITRA

TABLE 11 ABUNDANCE OF SCLERACTINIA AT NARARA AND POSHITRA COASTAL REEFS

Scleractinia/Alcyonaria		
Scientific Name	**Narara**	**Poshitra**
Homophyllia bowerbanki	1.662	1.34
Cyphastrea serailia	2.30	1.34
Dipsastraea speciosa	5.88	6.25
Dipsastraea favus	11.50	9.04
Goniopora pedunculata	5.11	9.67
Goniopora nigra	4.85	7.93
Montipora foliosa	5.49	0
Montipora sp.	1.02	1.80
Porites lichen	8.31	5.72
Porites lutea	10.99	7.27
Porites solida	0	4.34
Porites compressa	0	2.20
Lobophyllia radians	3.70	2.36
Lobophyllia sp.1	6.13	2.56
Favites bestae	1.15	1.77
Favites complanata	7.92	3.45
Siderestrea savignaya	7.41	2.33
Leptastrea purpuria	3.19	0
Duncanopsammia peltata	2.17	17.67
Turbineria reniformis	0	2.79
Platygyra sinesis	2.30	1.21
Pseudosiderastrea tayamai	1.27	0.427
Goniastrea pectinata	4.34	2.76
Paracyathus stokesii	3.19	1.61
Plesiastrea versipora	0	0.49

Tubastea aurea	0	0.03
Sinuleria sp.	0	0.59
Dendronephtheya sp.	0	0.09

CRUSTACEA

At Narara total eleven species of crustacea were found (Fig.23, Table 12). The most abundant species was *Ancylocaris brevicarpalis* followed by *Portunus pelagicus* and *Scylla serrata*. The other species found included Pilumnus *vespertilio, Austruca lactea, Thranita crenata, whereas* those species in low abundance were *Demania sp., Alpheus sp*. and *Atergatis integerrimus.* The Poshitra coastal reef (Fig.24, Table 12) comprised of total twelve species of crustacean fauna. Their diversity and abundance varied from the Narara coastal reef. The most abundant species found here was *Cardisoma sp*. followed by *Pilumnus verspertilio* and *Thranita crenata*. The other species recorded were *Portunus pelagicus, Grapsus albolineatus, Atergatis integerrimus, Menippe rumphii*. The least found individuals were for Actea *savigynii*, Aplheaus *sp.* and *Camposcia retusa*.

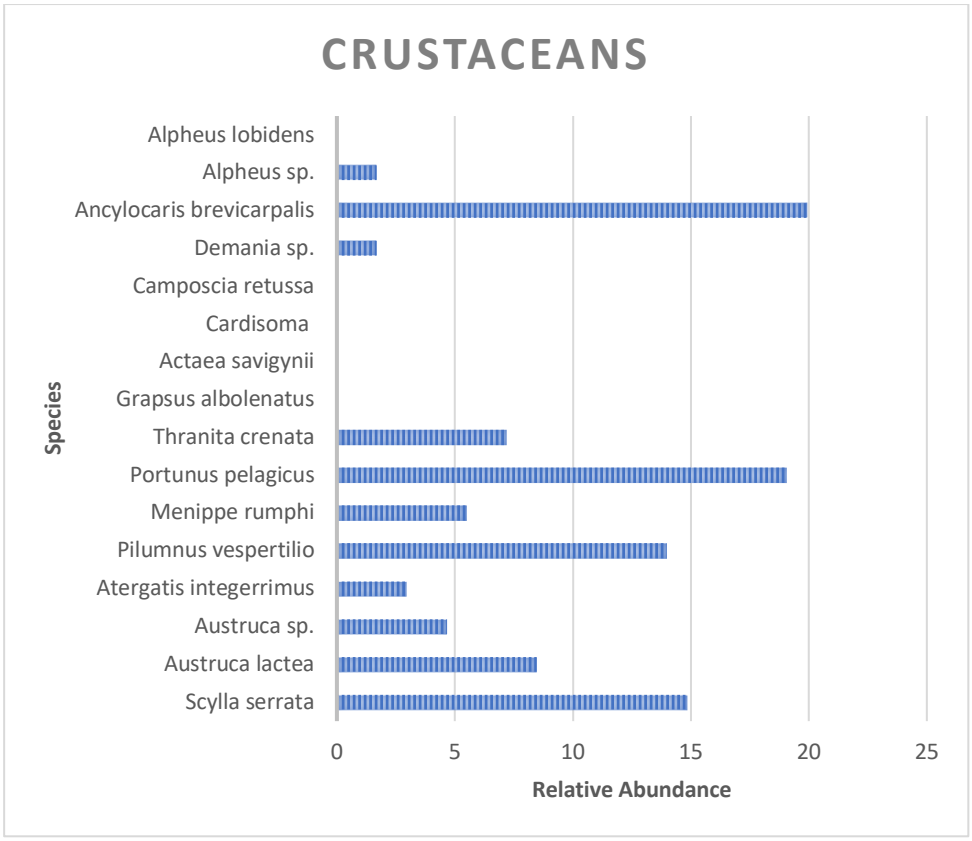


FIGURE 13 RELATIVE ABUNDANCE OF CRUSTACEA AT NARARA

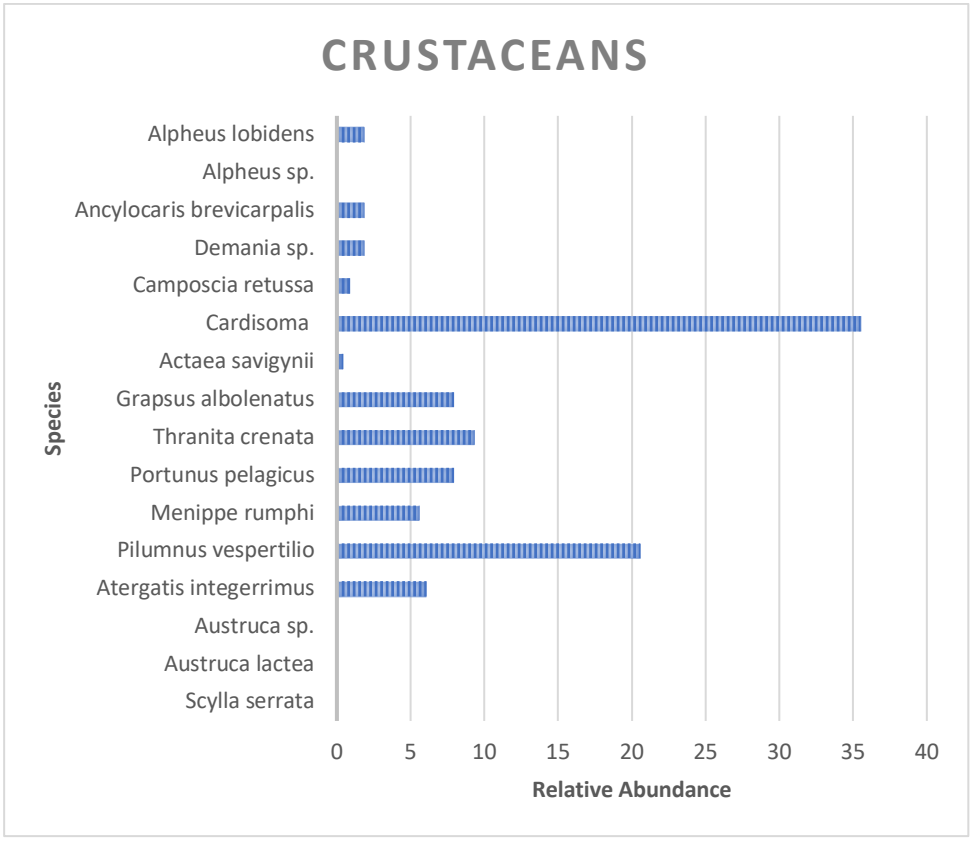


FIGURE 14 RELATIVE ABUNDANCE OF CRUSTACEA AT POSHITRA

TABLE 12 ABUNDANCE OF CRUSTACEA AT NARARA AND POSHITRA COASTAL REEFS

Crustacea		
Scientific Name	**Narara**	**Poshitra**
Scylla serrata	14.83	0
Austruca lactea	8.47	0
Austruca sp.	4.66	0
Atergatis integerrimus	2.96	6.07
Pilumnus vespertilio	13.98	20.56
Menippe rumphi	5.50	5.60
Portunus pelagicus	19.06	7.94
Thranita crenata	7.20	9.34
Grapsus albolenatus	0	7.94
Actaea savigynii	0	0.46
Cardisoma sp.	0	35.51
Camposcia retussa	0	0.93
Demania sp.	1.69	1.86
Ancylocaris brevicarpalis	19.91	1.86
Alpheus sp.	1.69	0
Alpheus lobidens	0	1.86

At Narara total sixteen species of Gastropods were found (Fig. 25, Table 13). The most abundant species found was *Umbonium vestiarium* (Table 11) followed by *Turbo intercostalis* and *Turbo bruneus.* The other species found were *Trochus niloticus, Pollia undosa, Gyrineum natator, Lunella coronata, Brusa granularis, Nerita oryzarum*. The least abundant species found were *Murex sp*. and *Natica picta*. The Poshitra coastal reef (Fig. 26, Table 13) had comparatively a greater number of gastropod diversities. Amongst the total twenty-one species observed *Bursa granularis* was the most abundant species encountered followed by *Trochus niloticus* and *Turbo intercostalis*. The other species encountered were *Chiton sp., Nerita oryzarum, Turbo bruneus, Umbonium vestiarium, Turitella terebra, Trochus radiatus, Telescopoium Telescopium, Gyrineum aculeatum, Cerithium scabridum, Chicoreus brunneus, Erronea onyx* and *Murex brunneus*. The least abundant individuals were *Murex sp., Tibia sp* and *Cymatium pileare*.

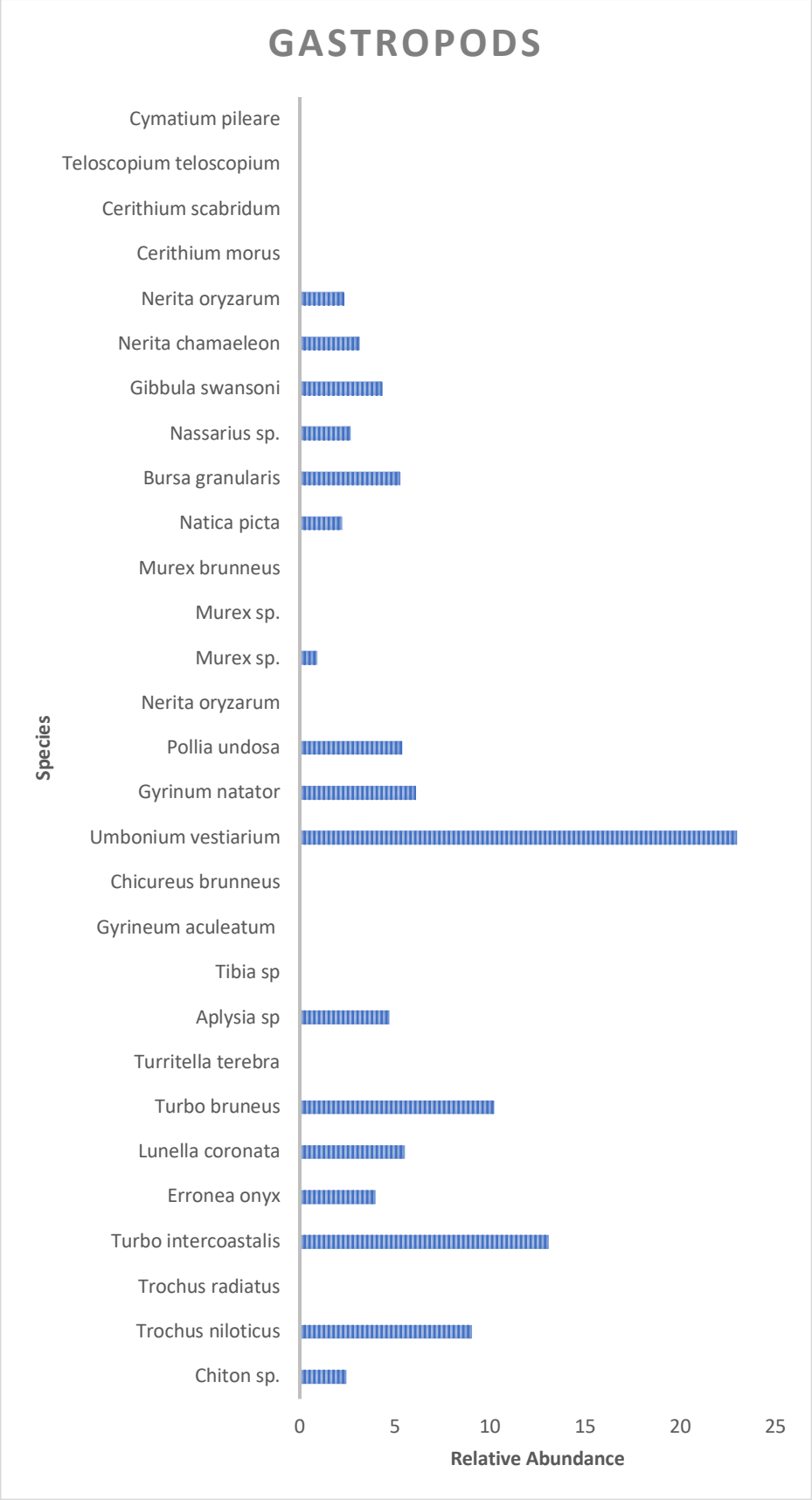


FIGURE 15 RELATIVE ABUNDANCE OF GASTROPOD AT NARARA

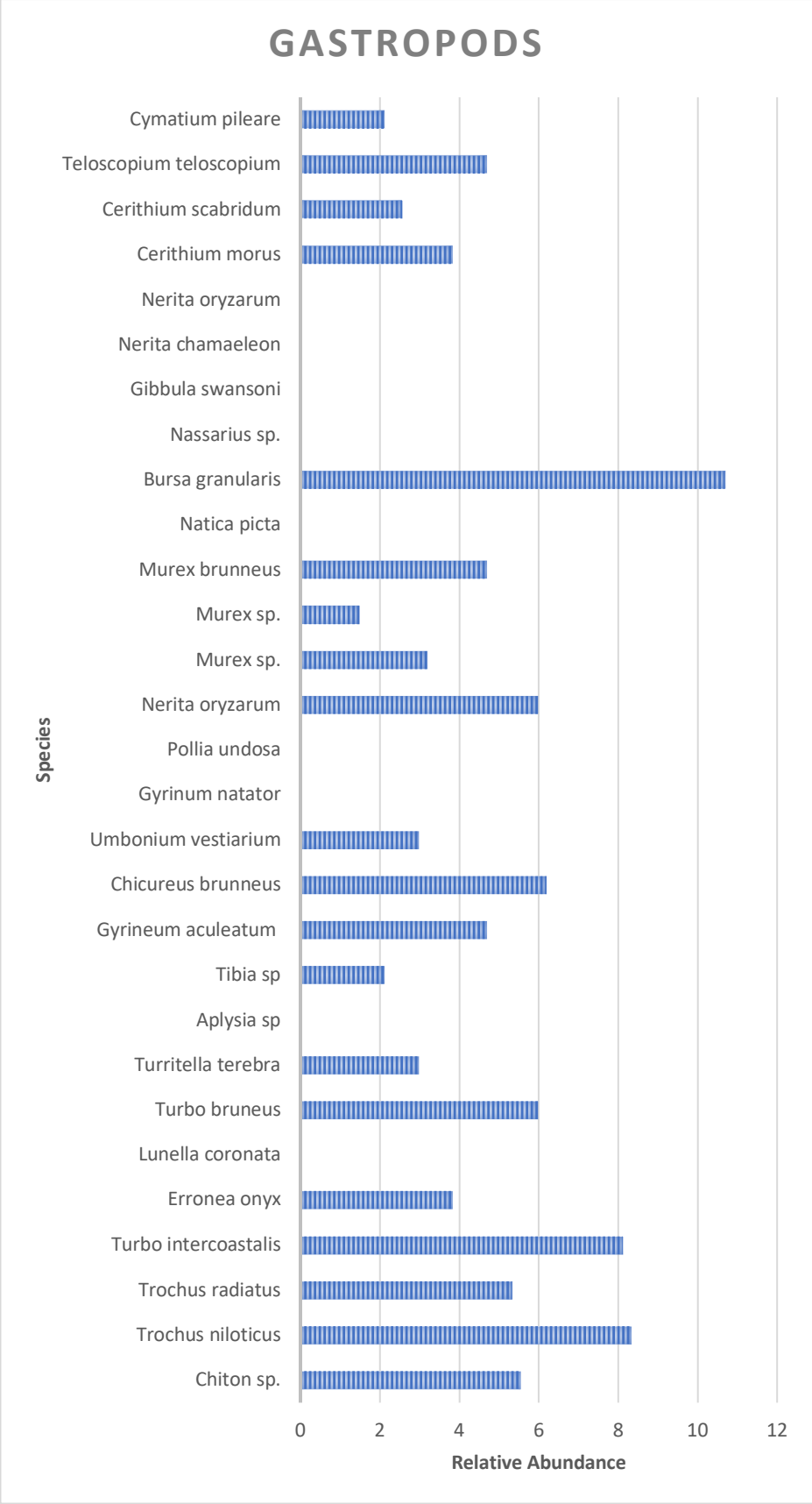


FIGURE 16 RELATIVE ABUNDANCE OF GASTROPOD AT POSHITRA

TABLE 13 ABUNDANCE OF GASTROPODA AT NARARA AND POSHITRA COASTAL REEFS

Mollusca: Class- Gastropoda

Chiton sp.	2.47	5.55
Trochus niloticus	9.06	8.33
Trochus radiatus	0	5.34
Turbo intercoastalis	13.07	8.11
Erronea onyx	4.00	3.84
Lunella coronata	5.53	0
Turbo bruneus	10.24	5.98
Turritella terebra	0	2.99
Aplysia sp.	4.72	0
Tibia sp.	0	2.13
Gyrineum aculeatum	0	4.70
Chicureus brunneus	0	6.19
Umbonium vestiarium	22.96	2.99
Gyrineum natator	6.12	0
Pollia undosa	5.41	0
Nerita oryzarum	0	5.98
Murex sp.	0.94	3.20
Murex sp. 1	0	1.49
Murex brunneus	0	4.70
Natica picta	2.23	0
Bursa granularis	5.30	10.68
Nassarius sp.	2.70	0
Gibbula swansoni	4.35	0
Nerita chamaeleon	3.18	0
Nerita oryzarum	2.35	0
Cerithium morus	0	3.84

Cerithium scabridum	0	2.56
Teloscopium teloscopium	0	4.70
Cymatium pileare	0	2.13

ANNELIDA

Annelida included only three species at Narara. *Sabellastrea indica* dominated followed by *Sabellastrea sp*. and *Nereis sp*. while at Poshitra The *Sabellastrea indica* dominated followed by *Nereis sp*. The number of individuals of *Sabellastrea indica* dominated at Narara. As the number of species and individuals encountered was low no statistical analysis could be done.

NUDIBRANCH

The nudibranchs were difficult to locate as the species are illusive in nature and well camouflaged. However, the data collected on these macrobenthos were to see the abundance in both the reefs. There were total four species of Nudibranchs present in Narara reef (Fig. 27) Table 14. The abundance of the *Jorunna funebris* was higher followed by *Elysia tomentosa* and *Aplysia sp*. The least found were *Hypselodoris infucata* and *Peltodoris murrea*. Poshitra coastal reef (Fig. 28) had four Nudibranchs present in the area. the most abundant was *Joruna funebris* followed by *Peronia verruculata* and *Sakuraeolis gujaratica* (endemic to Gujarat, India) sighted only at Poshitra reef. The least sighted one were *Trinchesia yamasui* and *Phidiana militaris*. Both the reefs differed in terms of diversity and abundance of nudibranchs.

Nudibranch

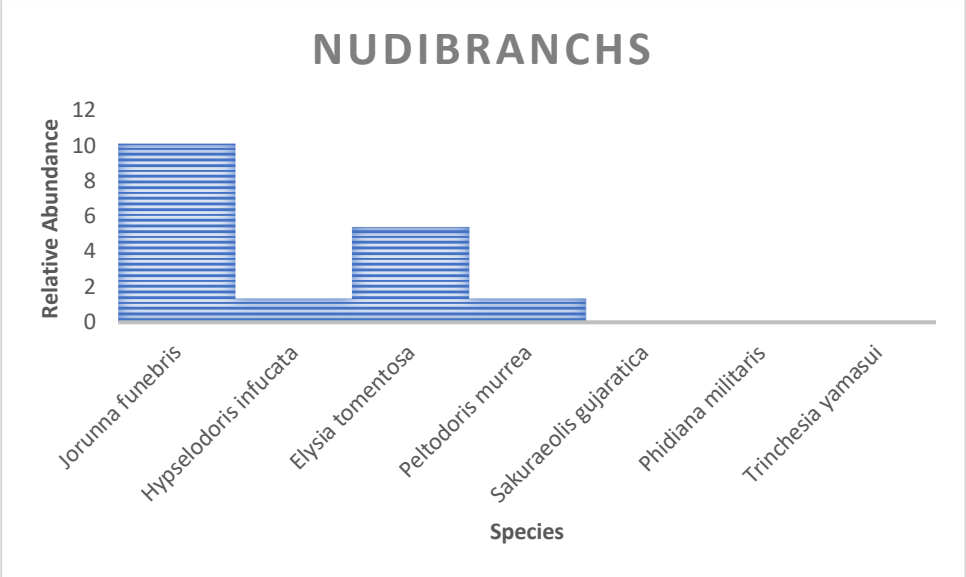


FIGURE 17 RELATIVE ABUNDANCE OF NUDIBRANCH AT NARARA

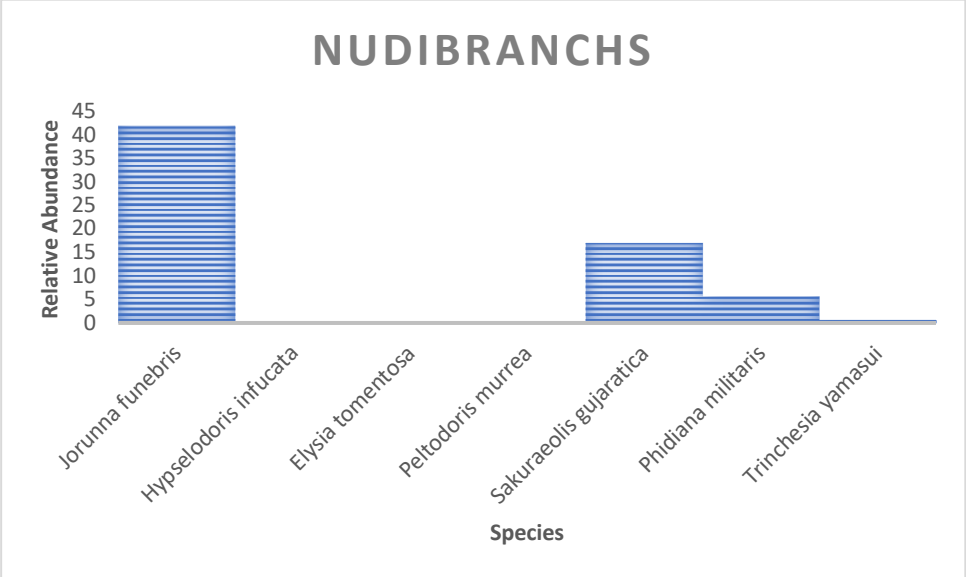


FIGURE 18 RELATIVE ABUNDANCE OF NUDIBRANCH AT POSHITRA

TABLE 14 ABUNDANCE OF NUDIBRANCH AT NARARA AND POSHITRA COASTAL REEFS

Mollusca: Order- Nudibranchia		
Jorunna funebris	10.13	41.77
Hypselodoris infucata	1.35	0
Elysia tomentosa	5.40	0
Peltodoris murrea	1.35	0
Sakuraeolis gujaratica	0	17.08
Phidiana militaris	0	5.69
Trinchesia yamasui	0	0.63

Total five species of Echinoderm were observed at Narara reef (Table 15, Fig. 29) with *Ophiopluteus imbricatus* having highest abundance values. This was followed by *Holothuria scabra* and *Asterina sp*. The least found were *Laganum depressum* and *Salmacis bicolor*. The Poshitra coastal reef (Table 15, Fig. 30) comprised of total four species. The most abundant species was *Asterina sp.* followed by *Holothuria scabra* and *Ophiopluteus imbricatus*. The *Ophiarachna affinis, Lamprometra sp*. and *Laganum depressum* were found to be least abundant in this coastal reef.

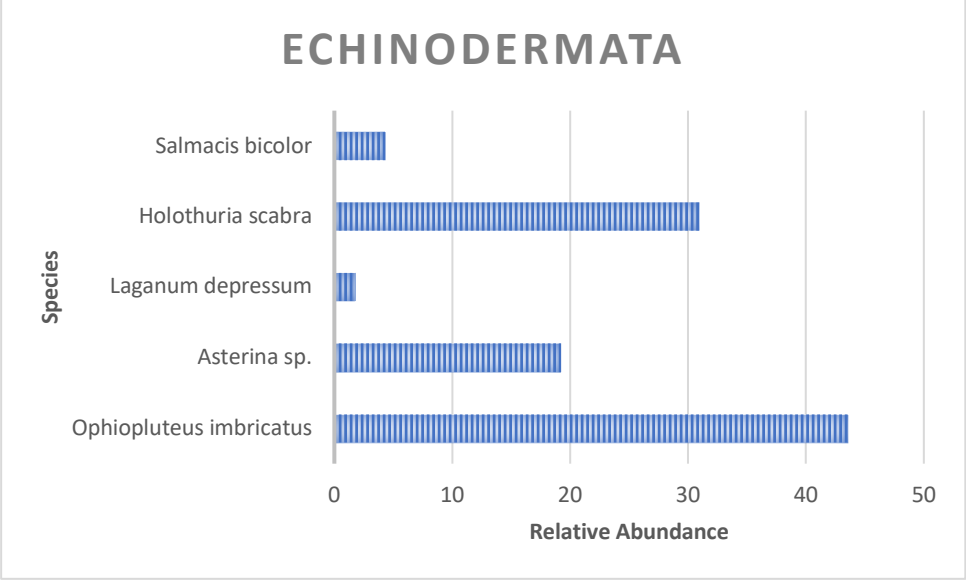


FIGURE 19 RELATIVE ABUNDANCE OF ECHINODERM AT NARARA

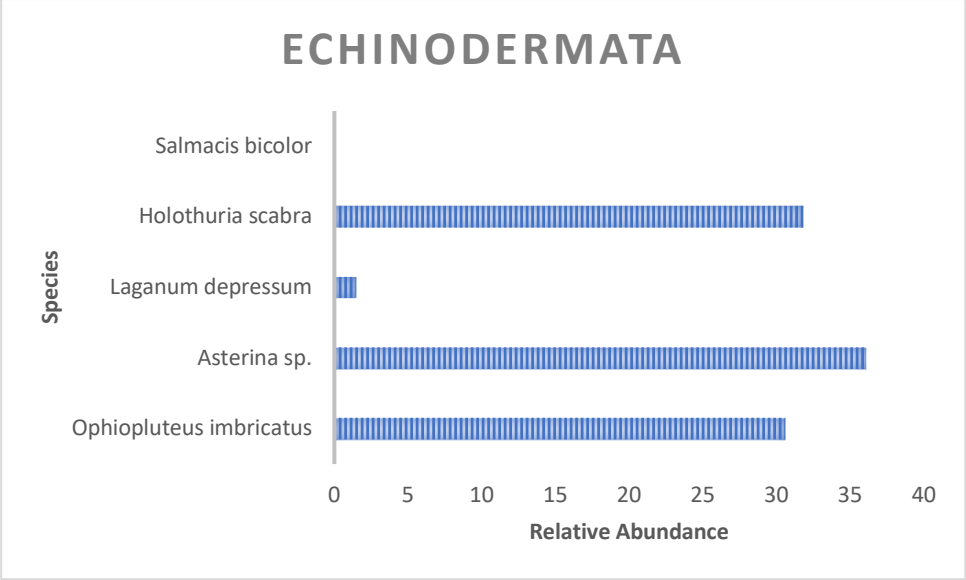


FIGURE 20 RELATIVE ABUNDANCE OF ECHINODERM AT POSHITRA

TABLE 15 ABUNDANCE OF ECHINODERMATA AT NARARA AND POSHITRA COASTAL REEFS

Echinodermata		
Scientific Name	**Narara**	**Poshitra**
Ophiopluteus imbricatus	43.57	30.60
Asterina sp	19.26	36.06
Laganum depressum	1.83	1.51
Holothuria scabra	30.96	31.81
Salmacis bicolor	4.35	0

At Narara coastal reef nine species of Pisces were observed (Fig. 31 Table 16). The abundance of *Epinephilus coioides* was maximum followed by *Allenbatrachus grunniens* and *Blenniella sp*. Other fishes observed include *Tetraodon lineatus, Epinephilus malabaricus,* and *Halichoeres nigrescens*. The least abundant were *Mugil cephalus, Neotrygon kuhlii* and *Plotosus lineatus*. The Poshitra coastal reef (Fig. 32 Table 16) had six species with *Abudefduf sordidus* as the most abundant followed by *Allanbatracus grunniens* and *Epinephelus coioides*. The least found species were of *Blenniella sp., Mugil cephalus and Tetrodon lineatus*.

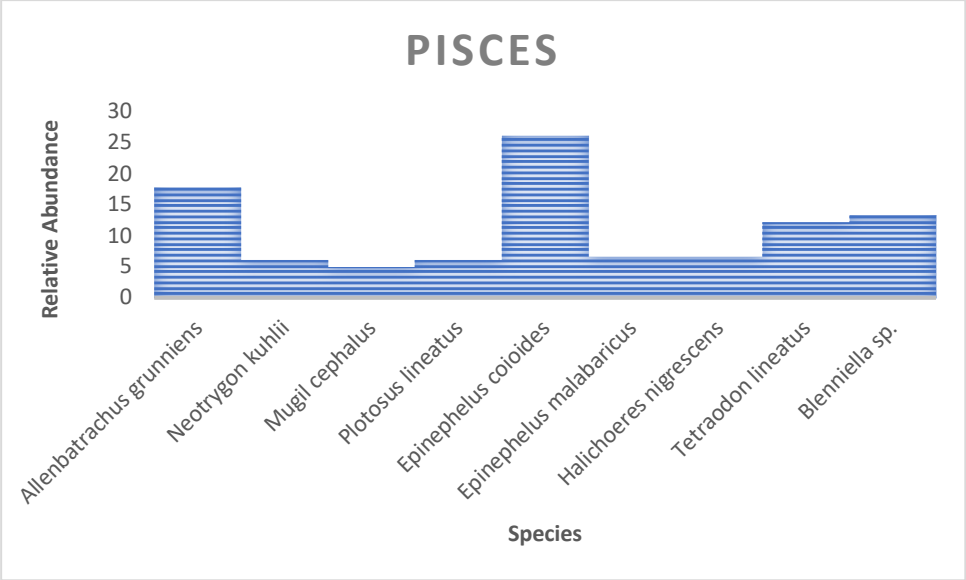


FIGURE 21 RELATIVE ABUNDANCE OF PISCES AT NARARA

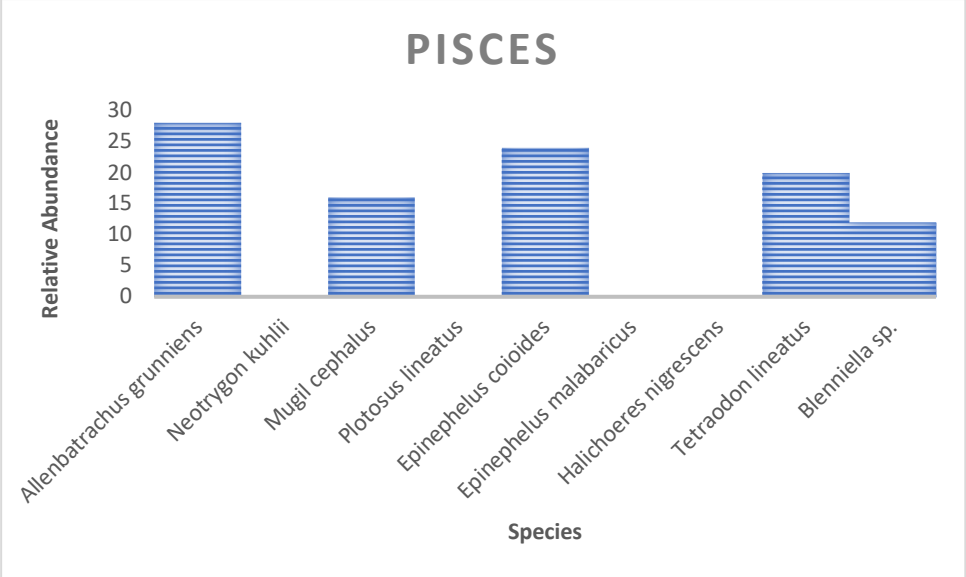


FIGURE 22 RELATIVE ABUNDANCE OF PISCES AT POSHITRA

TABLE 16 ABUNDANCE OF PISCES AT NARARA AND POSHITRA COASTAL REEFS

Pisces		
Scientific Name	**Narara**	**Poshitra**
Allenbatrachus grunniens	17.77	28
Neotrygon kuhlii	6.11	0
Mugil cephalus	5	16
Plotosus lineatus	6.11	0
Epinephelus coioides	26.11	24
Epinephelus malabaricus	6.66	0
Halichoeres nigrescens	6.66	0
Tetraodon lineatus	12.22	20
Blenniella sp.	13.33	12

Phylum wise representation of individuals of the various phyla studied is plotted as boxplots to understand the differences in status of these phyla (Fig. 33 Narara, Fig. 34 Poshitra). In Narara coastal reef, the majority of counts that go away from the average number of individuals were of Echinoderm and has greater differences in numbers of individuals observed per visit by having high median value. Similarly, in Cnidaria and Porifera the differences in numbers sited are higher but the medians varied in comparison to Echinoderm. However, their medians fall in the normal central tendencies of the total sightings of the individuals at Narara. Annelida, Crustaceans, Platyhelminthes and Pisces showed occurrence skewed to the right. The least encountered group of individuals belonged to the Platyhelminthes. The outliers were spotted in Cnidaria, Mollusca and Pisces showing the contrast of sightings with regard to each phylum.

Figure 34 shows variations in the sightings status in regard of individuals encountered for different phyla at the Poshitra coastal reef. The Annelida, Crustacea, Mollusca and Porifera were negatively skewed indicating that the sighting of the individuals was low contrary to the other phyla. However, the Cnidaria had higher number of outlier and also in highest number of *Heteractis malu* was encountered with maximum individuals (1140 Nos.) during one visit. The higher median values were found in Cnidaria and Echinodermata giving an understanding of varied number of sightings in both the categories. The Platyhelminthes and Pisces were found with low median values.

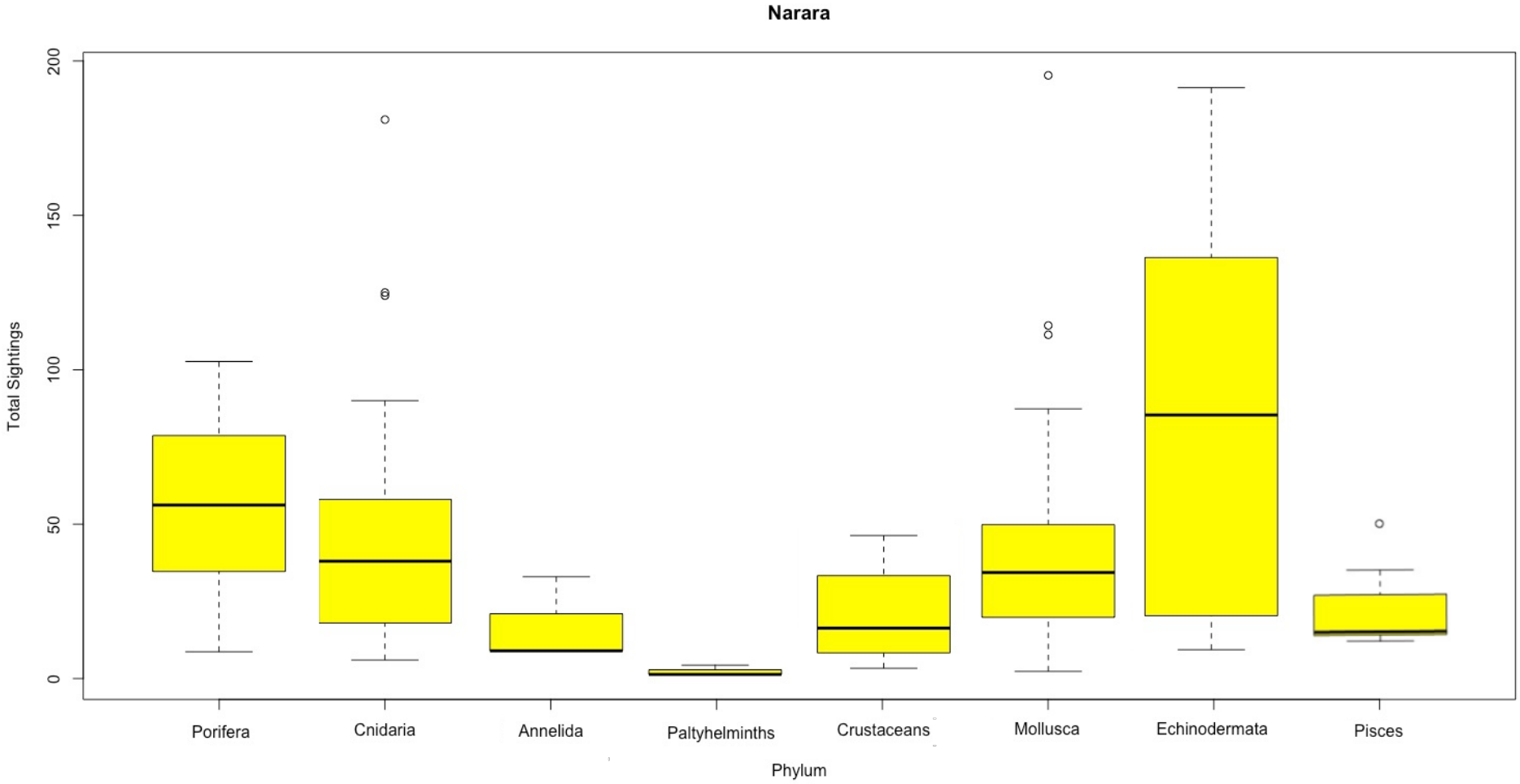


FIGURE 23 PHYLUM WISE MEAN REPRESENTATION OF INDIVIDUALS OBSERVED IN NARARA COASTAL REEF

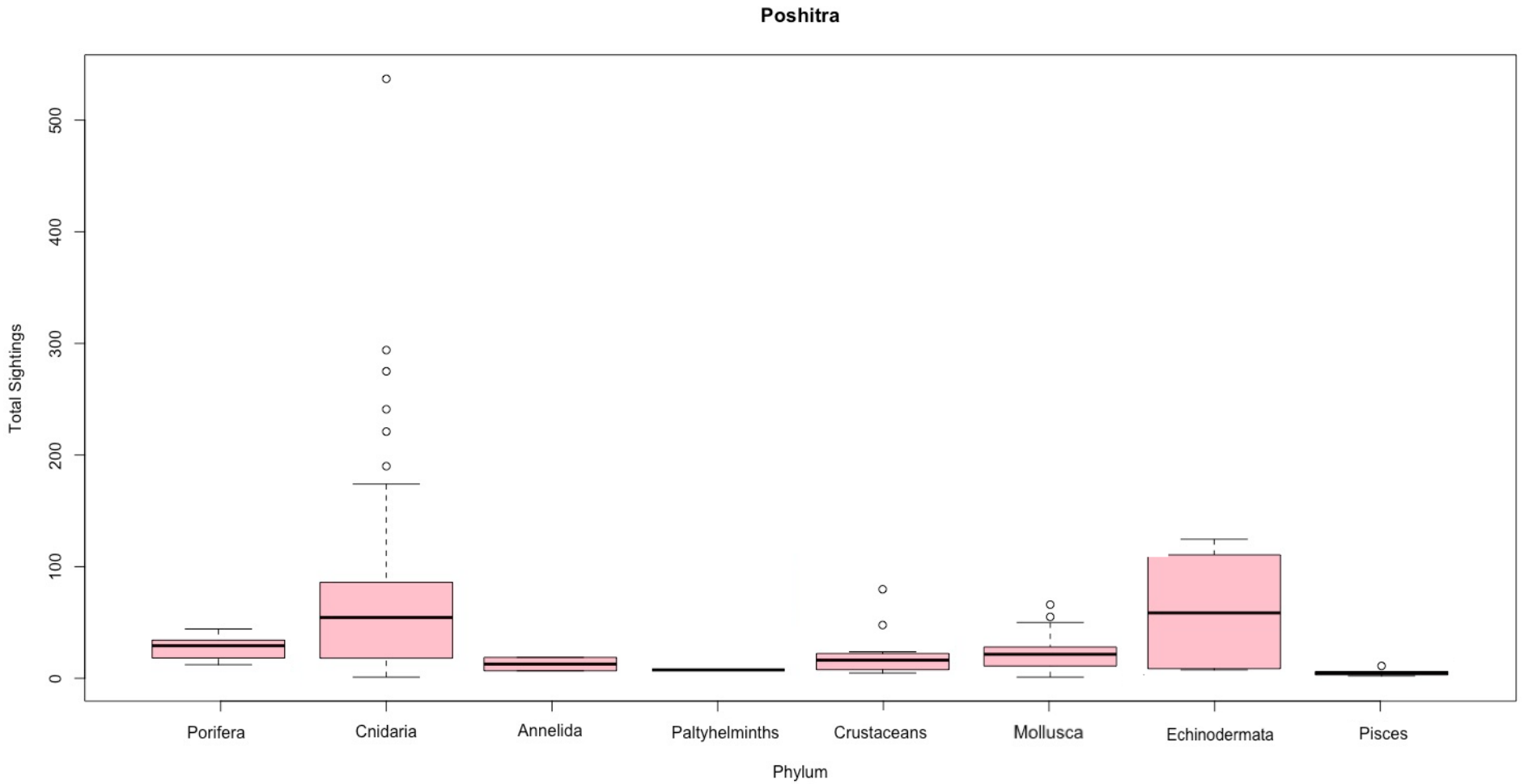


FIGURE 24 PHYLUM WISE MEAN REPRESENTATION OF INDIVIDUALS OBSERVED IN POSHITRA COASTAL REEF

The density histograms (Fig. 35) of individuals in different phylum at Narara and Poshitra were plotted to understand the patterns of distribution of individuals. Narara reef had median values from 0,10, 20, 30,…70. Total 7 class intervals were obtained. The most species occurred in the values of 0-10. Their density was 0.07 in Narara. The second most density value was 0.02 and it comprised of 10-20 class interval. Rest of the individuals in the phylum were falling to the low-density plots between 0.00 - 0.01. This showed that the encounter rate of the individuals in Narara were low at the higher-class intervals and high at the lower-class intervals.

The Poshitra reef (Fig. 36) obtained 9 class intervals with values from 0-90. Here, the highest density rate was more than 0.08 in the first-class interval of 0-10 and the second most was found in 10-20 at the density rate of 0.01. The third density class was between 0.00-0.01, forth class interval at 30-40. Rest encounter density rates were found below 0.01. Both the study sites did not show the normal distribution of the total individuals encountered.

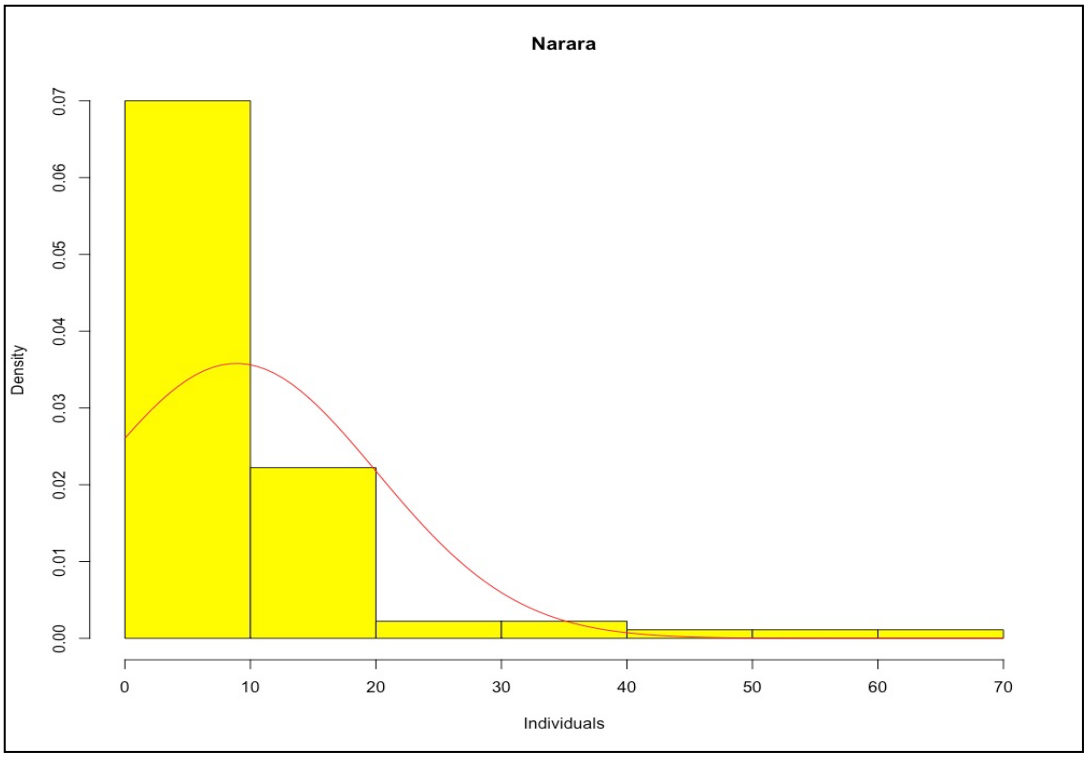


FIGURE 25 DENSITY HISTOGRAM OF PHYLUMS IN NARARA

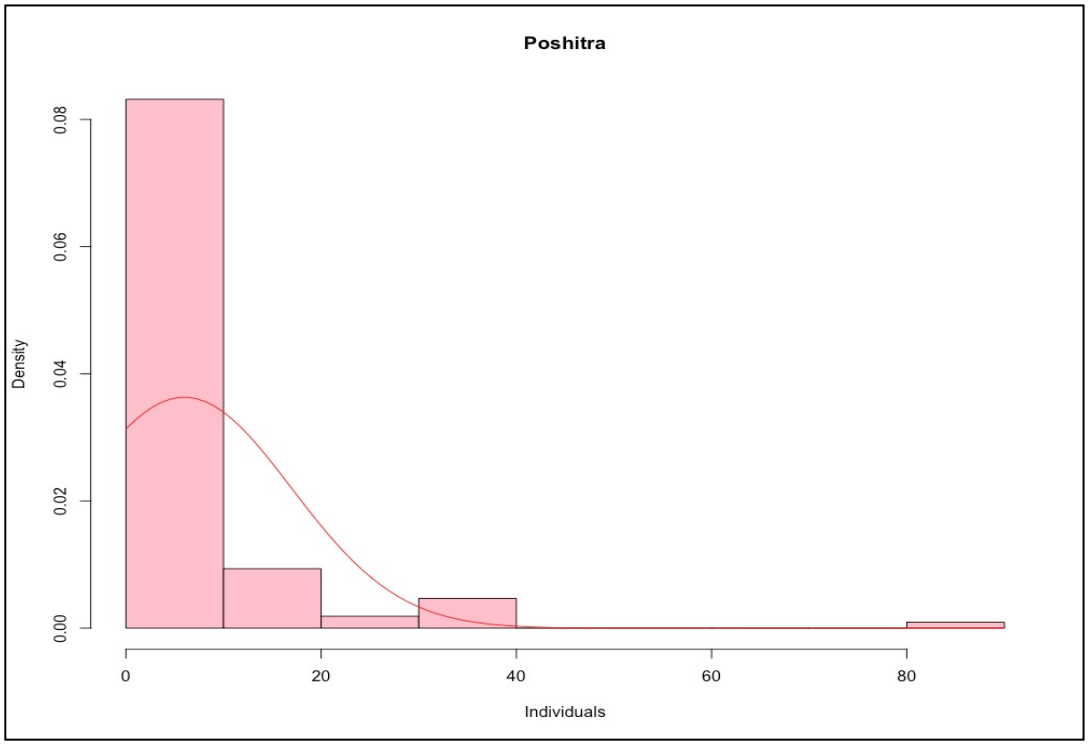


FIGURE 26 DENSITY HISTOGRAM OF PHYLUMS IN POSHITRA

The mean values of physicochemical variables of gulf water with calculated Standard deviations are given in table 17. The mean SST for Narara water was 27°C ±1.94 and that for Poshitra was 26.22°C ±1.77 while mean pH were 7.9 ±0.09 and 7.8 ±0.11 respectively and mean DO was 7.55 mg/L ±0.64 and 8.06 mg/L ±0.28 for respectively. The mean Salinity for Narara water was 37.55 ppt ±0.93 and for Poshitra water 38.08 ppt ±0.74. Amongst the nutrients studied mean Nitrate level for Narara water was 0.81 ppm ±0.08 and for Poshitra water 0.84 ppm ±0.02, while mean Nitrite levels were 2.42 ppm ±0.26 and 1.63 ppm ±0.11 respectively. The mean Phosphate level for Narara water was 1.48 ppm ±0.12 and that for Poshitra 1.96 ppm ±0.15.

Both the reefs did not show much difference in mean sea surface temperatures, pH, DO, Salinity, Nitrate, Nitrite and Phosphate throughout the study tenure.

TABLE 17 MEAN VALUES OF EACH VISIT OF DIFFERENT PHYSICOCHEMICAL PARAMETERS STUDIED AT NARARA AND POSHITRA COASTAL REEFS

Variables	NARARA	POSHITRA	t-test
SST °C	**27.45**	**26.22**	**n.s**
S.Dev	1.94	1.77	
pH	**7.91**	**7.84**	**n.s**
S.Dev	0.09	0.11	
DO mg/L	**7.55**	**8.06**	*
S.Dev	0.64	0.28	
Salinity ppt	**37.55**	**38.08**	**n.s**
S.Dev	0.93	0.74	
Nitrate ppm	**0.81**	**0.84**	*
S.Dev	0.08	0.02	
Nitrite ppm	**2.42**	**1.63**	**n.s**
S.Dev	0.26	0.11	
Phosphate ppm	**1.48**	**1.96**	*
S.Dev	0.12	0.15	

The Pearson correlation test was performed to find out if any relation exists between various physicochemical parameter studied in the Sea water collected from Narara and Poshitra coastal reefs (Table No. 14). At Narara (Fig. 37) there was positive correlation between SST and pH, DO, Salinity, Nitrate and Nitrite; whereas negative correlate to Phosphate. The pH was positively correlated with DO and Nitrate. Whereas it was negatively related with Salinity, Nitrite and Phosphate. The DO was positively correlated with Nitrate. Whereas it was negatively correlated with Salinity, Nitrite and

Phosphate. The Salinity was Positively correlated with Nitrate, Nitrite and Phosphate. The Nitrate was positively corelated to Nitrite, whereas negatively correlated to Phosphate. None of the parameters studied showed any significant relation with each other.

At Poshitra, (Fig. 38) the SST was positively correlated to pH, Salinity, Nitrate and Phosphate and negatively correlating to DO and Nitrite. The pH was positively correlated to Salinity and Nitrate and negatively correlated to DO, Nitrite and Phosphate. The DO was positively correlate with Nitrite and Phosphate, whereas it was seen negatively correlated with Salinity and Nitrate. The salinity was positively correlated with Nitrate, Nitrite and Phosphate. The Nitrate was negatively correlated with Nitrite and Phosphate. The Nitrite was positively correlated with Phosphate. As noted for Narara, here also no significant correlations were obtained between various parameters studied.

TABLE 18 CORRELATION BETWEEN DIFFERENT PHYSICOCHEMICAL PARAMETER OF SEA WATER OF NARARA AND POSHITRA COASTAL REEF

NARARA	SST	pH	DO	S	Nitrate	Nitrite	Phosphate
SST							
pH	0.26						
DO	0.12	0.60**					
S	0.56**	-0.13*	-0.40*				
Nitrate	0.54**	0.64**	0.55**	0.34			
Nitrite	0.48**	-0.25*	-0.07*	0.74**	0.33		
Phosphate	-0.11*	-0.24*	-0.37*	0.55**	-0.005*	0.43**	

POSHITRA	SST	pH	DO	S	Nitrate	Nitrite	Phosphate
SST							
pH	0.38						
DO	-0.13*	-0.22*					
S	0.37	0.24	-0.13*				
Nitrate	0.73**	0.77**	-0.29*	0.46**			
Nitrite	-0.38*	-0.32*	0.39	0.16	-0.54*		
Phosphate	0.36	-0.15*	0.34	0.06	-0.11*	0.15	

** Positive correlation, * negative correlation

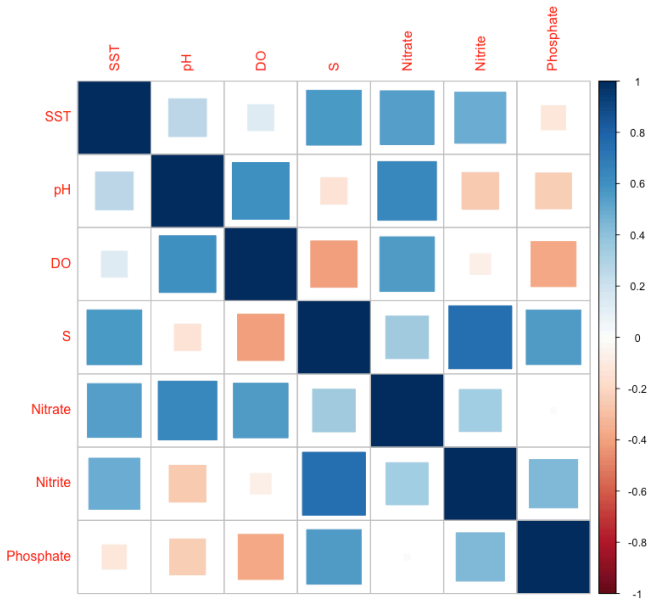


FIGURE 27 CORRELATION OF PHYSICOCHEMICAL PARAMETERS IN NARARA

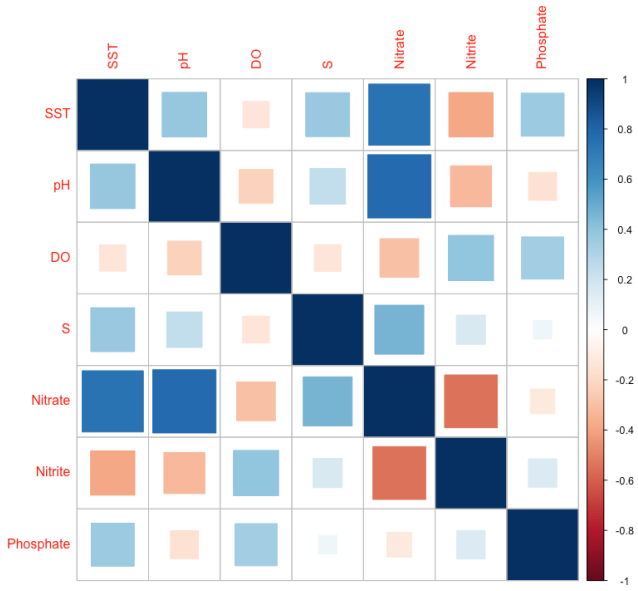
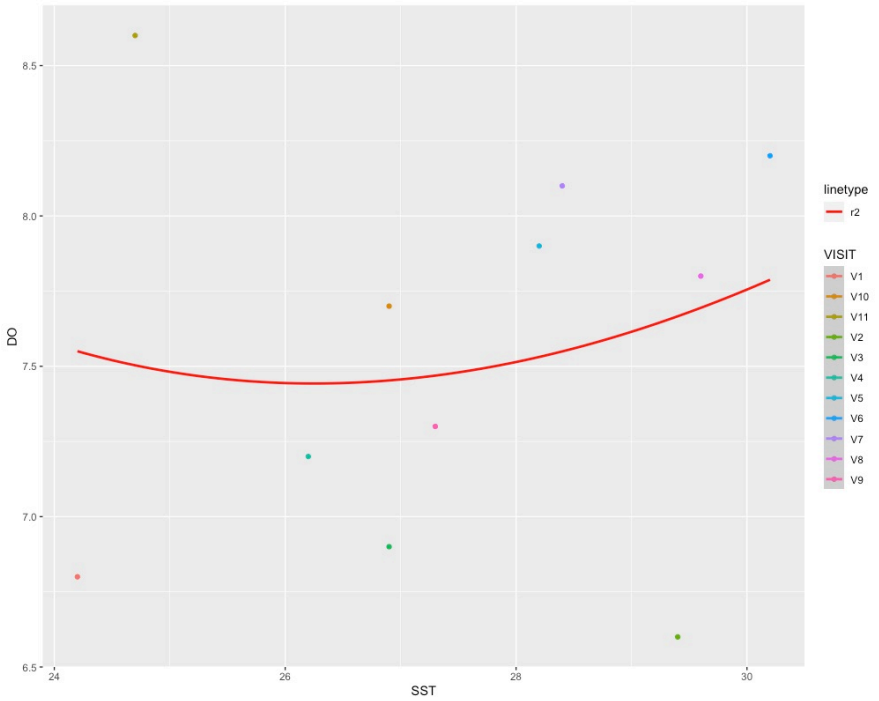


FIGURE 28 CORRELATION OF PHYSICOCHEMICAL PARAMETERS IN POSHITRA

The correlation matrix plot (Fig. 37 and Fig. 38) for physicochemical parameter was made to show the correlations at both the sites. The scale bar shows the correlation value between 1 to -1. The colour code signifies the levels of correlations in positive and negative values. The box matrix shows the fulfilment of values by signifying the filling and shrinking box.

FIGURE 29 CORRELATION BETWEEN SST AND DO

a. Narara



b. Poshitra

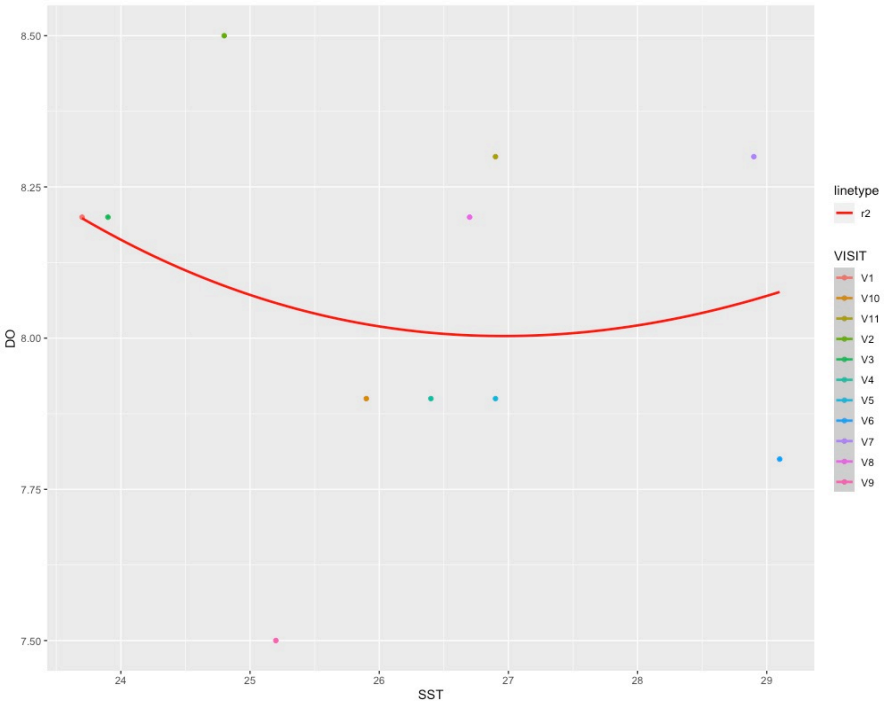
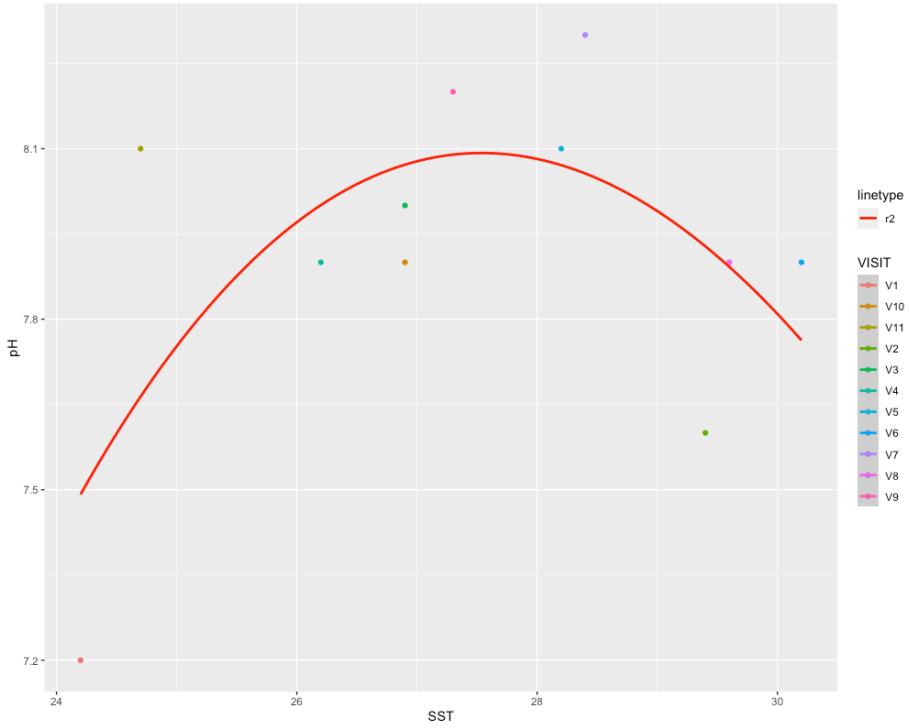


FIGURE 30 CORRELATION BETWEEN SST AND PH

a. Narara



b. Poshitra

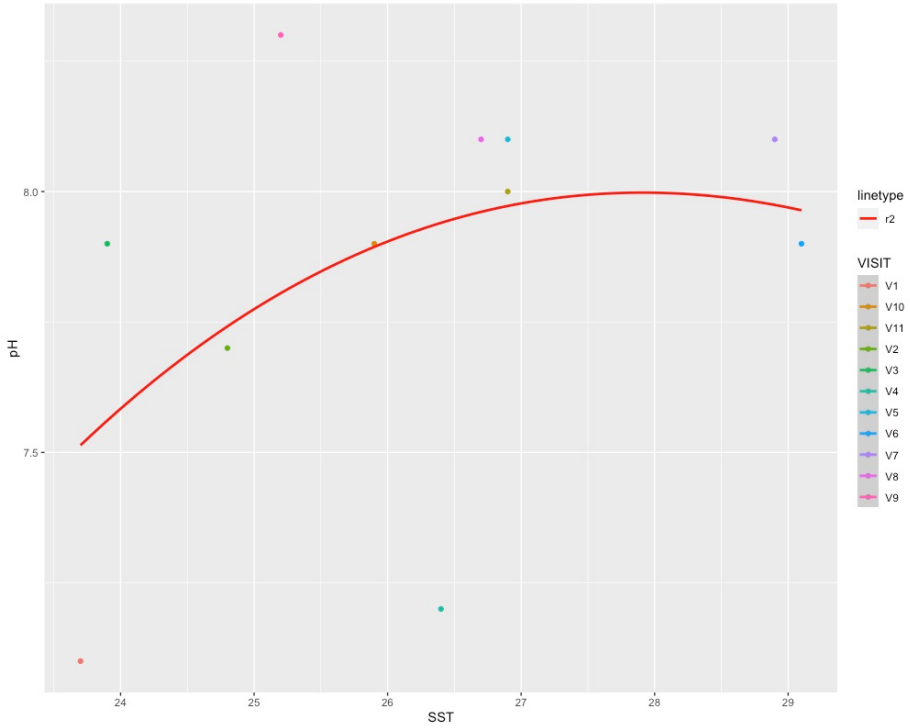
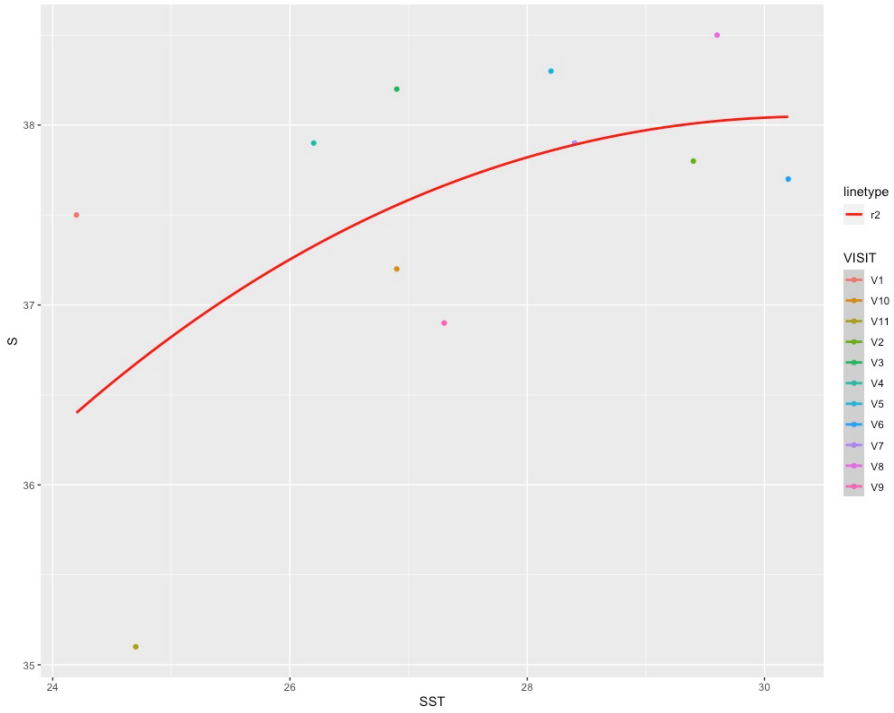


FIGURE 31 CORRELATION BETWEEN SST AND SALINITY

a. Narara



a. Poshitra

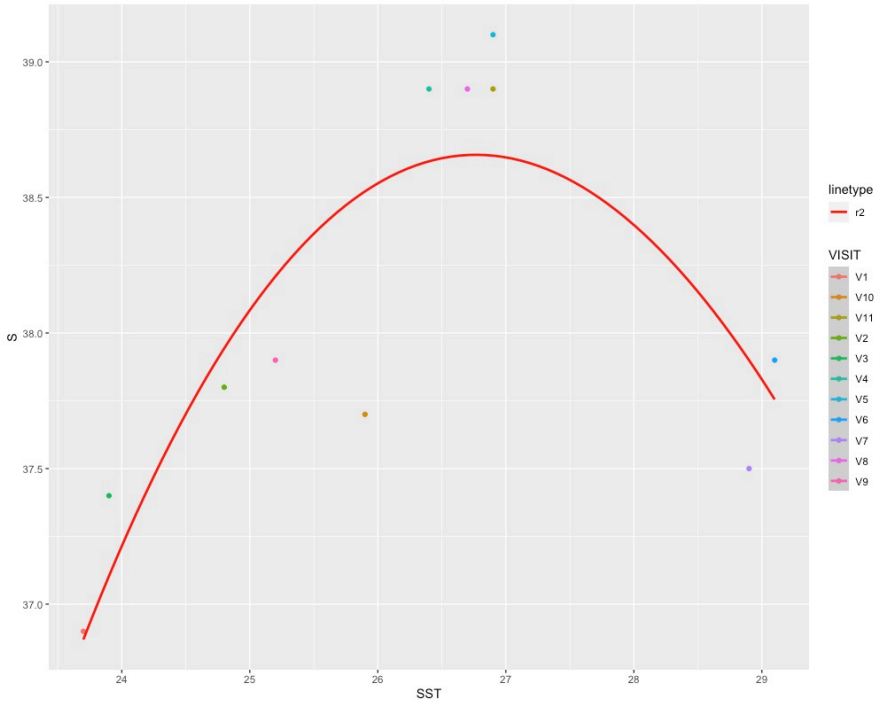
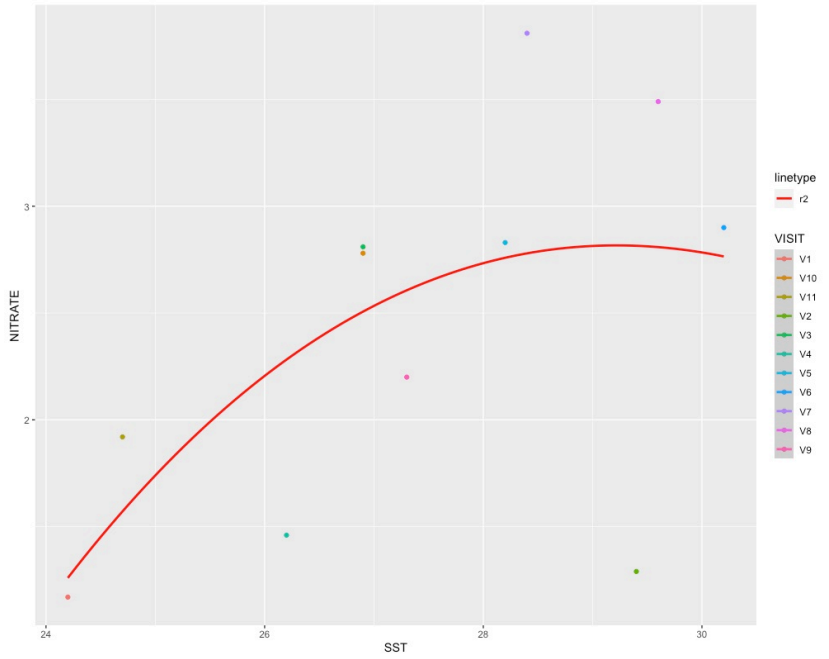


FIGURE 32 CORRELATION BETWEEN SST AND NITRATE

a. Narara



b. Poshitra

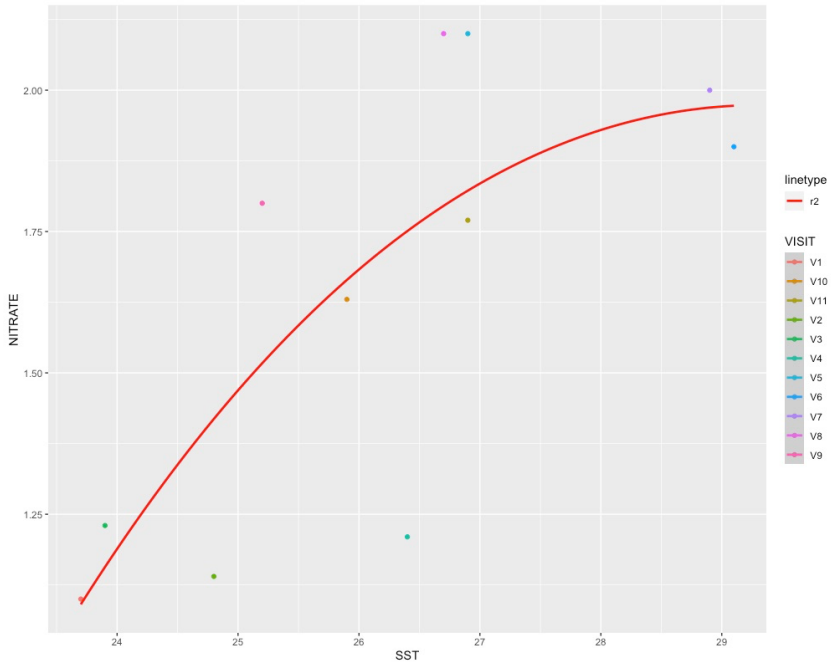
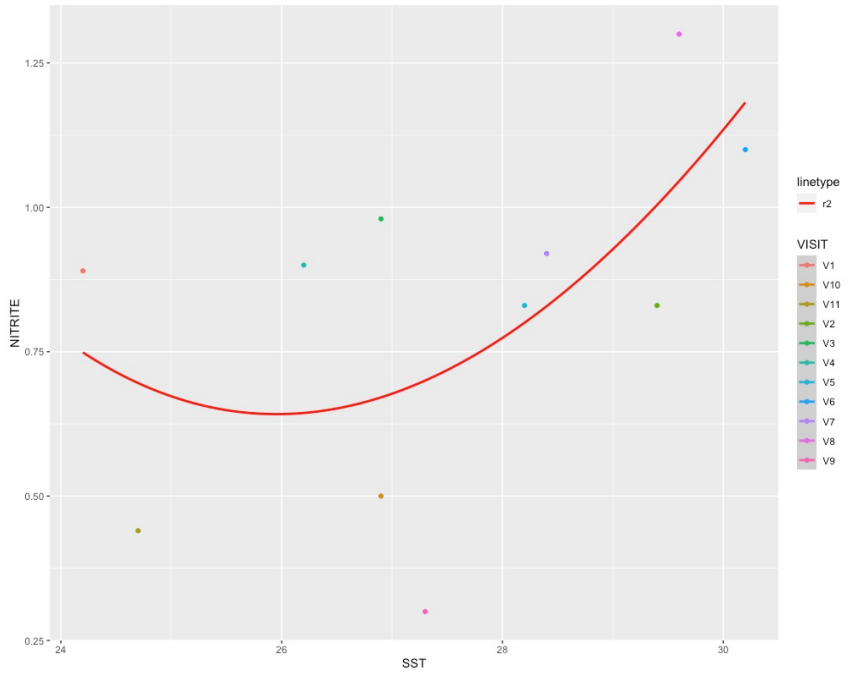


FIGURE 33 CORRELATION BETWEEN SST AND NITRITE

a. Narara



b. Poshitra

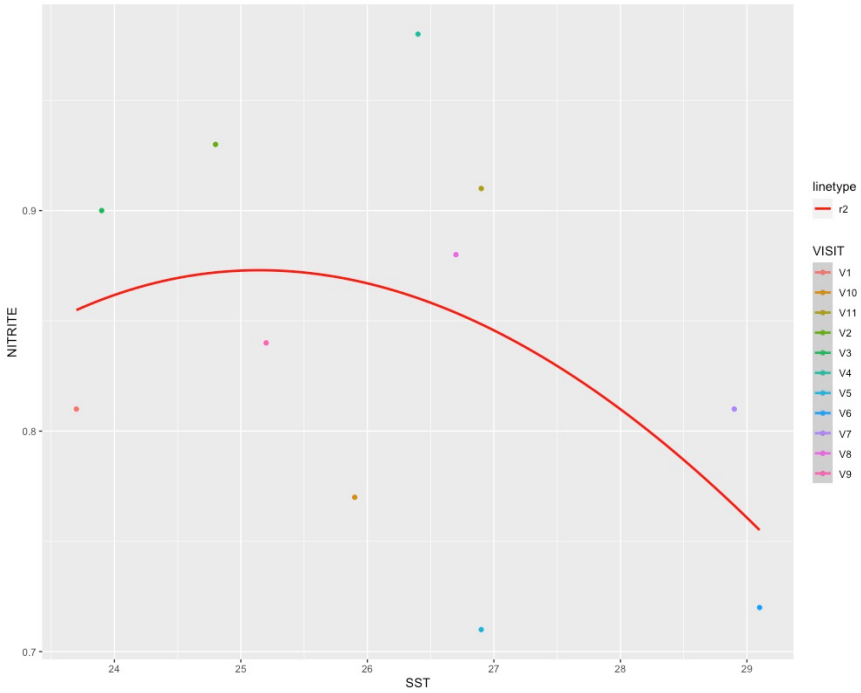
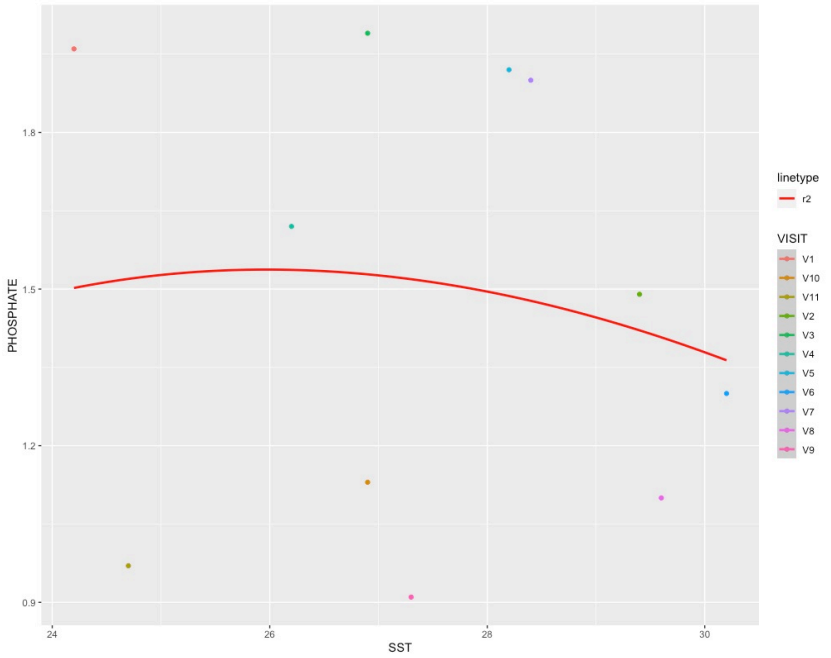
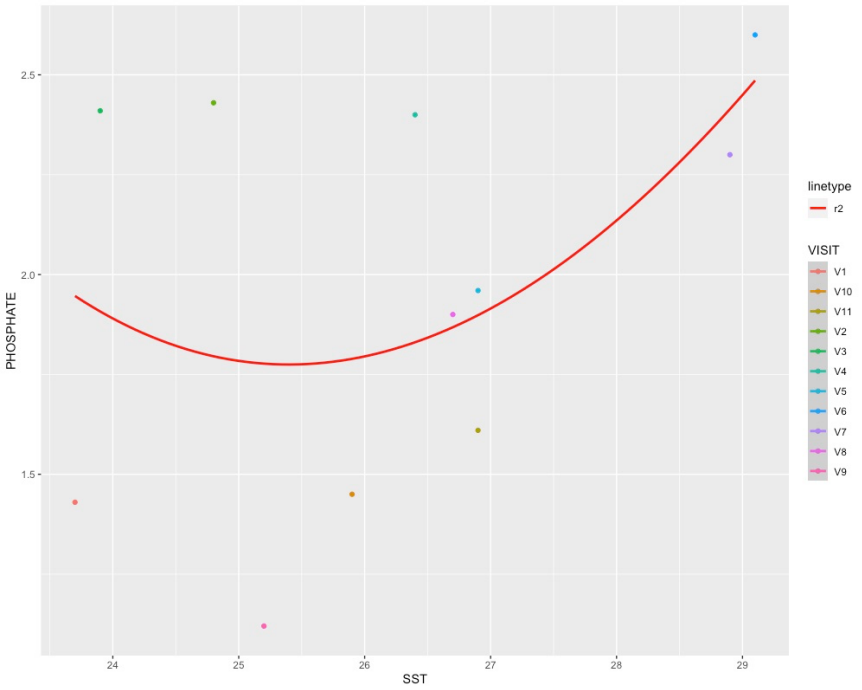


FIGURE 34 CORRELATION BETWEEN SST AND PHOSPHATE

a) Narara



b) Poshitra



NARARA

An attempt was made to correlate various physicochemical parameters with the Sea Surface Temperature with graphical grammar plot using linear model to see the relationship between each dependant variables and the trendlines. The relationships shown in Figures give variations in trendlines and the values nearest to the line. The Sea Surface Temperature is taken as an independent factor with the other physicochemical parameters such as Dissolved Oxygen (DO), pH, Salinity, Nitrate, Nitrite and Phosphate as dependent factors.

The graph showing relation between SST and DO for Narara reef (Fig. 39a) indicate that the point of dependent factors was not so closely lying to the trend line and showed quadratic trend. Fig. 40a shows correlation of pH against SST with curvilinear trend line while Figure 41a shows logarithmic trend line. The Nitrate against SST (Fig. 42a) showed correlation with the increase in SST. The points were found to be moderately sparse along the trendline which gave logarithmic expression of the graph. However, the correlation of Nitrite against SST (Fig. 43a) showed downward quadratic expression trend line. The values were more often found towards SST between 26 -28^{o}C. There was correlation of the Nitrate that was increasing with the increase in Sea Surface Temperature. The Fig. 44a shows correlation of Phosphate against SST. The points in the graph are seen away from the trend line showing no significance with the increase in temperature. The curve is nonlinear showing negative relation with the dependant variable.

POSHITRA

The correlation of DO against SST at Poshitra also depicted a quadratic trend line (Fig. 39b). The two points are far away from the dependent factor and showing no correlation. The Fig. 40b shows correlation of pH against SST and maximum values were found to be correlating with the increasing SST at the Poshitra coastal reef. However, the trend line was giving a logarithmic curve as the SST was rising. The salinity (Fig. 41b) against SST was showing curvy linear trend line. Majority of the points were seen at the temperatures between 25 -28 ^{o}C along the trend line. The dependent factors were seen in moderate correlation and were seemed to be dispersed at different points. The Nitrate correlation against SST showed low correlation with the increased SST levels (Fig. 42b). The trend line was a logarithmic curve depicting at higher SST. The points lying closely to the trend

line are showing that at higher SST the Nitrate levels seem to increase. The correlation of Nitrite against SST (Fig. 43b) shows curved trend line towards the higher temperatures. The points are found to be scattered away from the trend line showing no positive relation with increase in SST. The dependent factor is seen to be more dynamic at the temperatures ranging between 23 -27^{o}C. The Phosphate was correlated against the SST (Fig. 44b). Here, the trend line was giving a quadratic relation with independent factor. The dynamic range for Phosphate was between the temperatures ranging from 23 -27^{o}C. No such correlation was seen with Phosphate at the Poshitra coast reef.

Both the reefs showed two different lines as pH, Salinity and Nitrate had same directional progress whereas DO, Nitrite and Phosphate showed difference in the graph plot giving probability of involvement of other biotic and/or abiotic factors which need to be evaluated.

SUBSTRATUM CHARACTERISTICS:

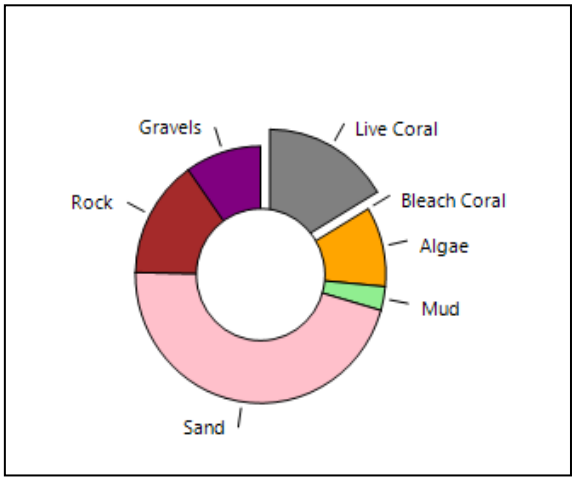


FIGURE 35 SUBSTRATUM CHARACTERISTICS OF NARARA REEF

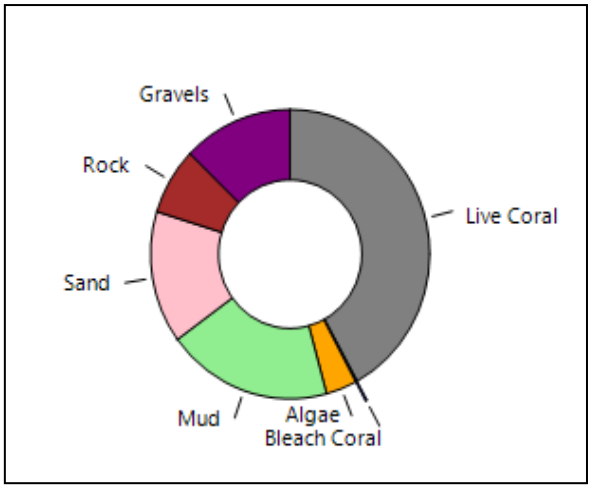


FIGURE 36 SUBSTRATUM CHARACTERISTIC OF POSHITRA REEF

TABLE 19 BENTHIC COVER AND HABITAT CHARACTERISTIC AT NARARA AND POSHITRA COASTAL REEFS

Coral and Substrate characteristics (%)	**NARARA**	**POSHITRA**
Benthic cover of Live Coral	16.43	42.07
Benthic cover of Bleach Coral	0	0.19
Benthic cover of Algae	10.06	3.57
Benthic cover of Mud	3	19.19
Benthic cover of Sand	45.76	14.8
Benthic cover of Rock	14.93	7.5
Benthic cover of Gravels	9.8	12.76

The Narara and Poshitra coastal reefs were also evaluated on the basis of their substrate characteristics (Table 19) based on the benthic cover of live coral, bleached coral, algae, mud, sand, rock and gravels. The live coral composition at Narara was 16% (Fig. 45) and that at Poshitra was 42% (Fig. 46). The bleached coral cover was not recorded during the study in Narara reef, while at Poshitra reef 0.19% of bleached corals were encountered. The algal cover at the Narara reef was 10.06% and that of Poshitra reef was 3.57%. The aggregation of algal growth differed at both the reefs. The mud cover near the corals in both the reefs also differed. There was only 3% of mud encountered in the Narara coastal reef and 19.19% of mud cover at Poshitra reef.

The sand was a major part in the Narara coastal reef along with the reef structure and the corals. The sand comprised the total 45.76% in the Narara and 14.8% in the Poshitra coastal reef. The rock composition at Narara was 14.93% towards the sea whereas; it was 7.5% in Poshitra. The benthic cover of gravels were found to be 9.8% in Narara and 12.76%. at Poshitra reef.