CHAPTER 3: MATERIALS AND METHODOLOGY

This chapter deals with the details of methods adopted for analysis of data. Various phases of methodology used to carry out the study are discussed under the following sub-heads.

3.1 STUDY AREA

Corals are found in tropical and subtropical waters all over the world and one of the oldest and most dynamic reef systems is in India. India has an overall coastline length of 7517 km, including islands. The nation's coastline region is fortunate to have a huge network of estuaries, creeks, lagoons, backwaters, and specialist ecosystems like mangroves and coral reefs. India contains around 2% of the world's coral reefs Spalding *et al.,* (2001), with Gujarat having one of the country's four major coral reefs, mostly in the Gulf of Kachchh.

The Gulf of Kachchh is situated on India's western coast between latitudes 22°15' to 23°40' N and longitudes 68°20' to 70°40' E. It is a funnel-shaped, east-west directed indentation of Gujarat's coast that is around 125 km long and 75 km broad. The shoreline in the Gulf of Kachchh is rugged, has a strongly crenulated configuration, and is distinguished by wide mudflats, distant islands, rocky platforms with little beaches and with 20% of the country's reef on the southern part of the gulf. The hard basalts and soft tertiary sedimentary rocks that make up the substrate of gulf are uneven and low gradient and calcareous mud are used to cover the littoral zone (GES, 1997). The Gulf of Kachchh's coral reefs is the Indian continent's most northernly distributed reef ecosystem. The Gulf of Kachchh has a noticeable coral distribution on the islands and in a few coastal areas along the mainland. Live corals can be seen Along the borders of the reef's offshore slope (Bahuguna *et al.,* 1992). Several endangered plant and animal species can also be found in this area (Dave, 2011). Of the 45 islands in the Gulf of Kachchh, coral reefs have been found on 42 of them (Joshi, 2016). The majority of the islands in the Gulf of Kachchh have fringing reefs, while some of the islands in the Gulf of Kachchh have a platform and patchy reefs (Dave, 2011). It covers a total area of 352.5 square kilometers with reefs (Jayaprakas and Radhakrishnan, 2014). The reefs of Gulf of Kachchh are considered as Marine Protected Areas (MPA), and the first officially recognized MPAs were the Marine Sanctuary and National Park, which were established in 1980 and 1982, respectively, under the Wildlife (Protection) Act, 1972. The MNP&S is located in the Northern Saurashtra intertidal zone, spanning to almost 150 km in the Gulf of Kachchh, and is a part of the Jamnagar and Devbhumi-Dwarka districts. The 620.81 km^2 Marine Protected Area (MPA) is made up of 148.90 km^2 of island area and 309.02 km^2 of intertidal zones along the shore. 162.89 km^2 of that land is a national park, and the remaining is a sanctuary (Singh *et al.,* 2004).

Due to the weak monsoonal rainfall and high evaporation rate, which in turn causes the seawater salinity to rise, the Gulf of Kachchh is a semi-arid zone. Throughout the year, the air temperature in the GoK ranges from 10°C to 36°C, and storms that occur in June and July have a significant impact on this area and have severe impacts on coastal areas (Joshi, 2016). Although the reef ecosystem of GoK is habituated to these extreme weather conditions, some visible impacts on corals and many other marine diversities can be seen at some of the reefs of GoK. Out of these many reefs, two places named Poshitra and Narara have been considered in this study to observe the visible effects on the corals of these reefs.

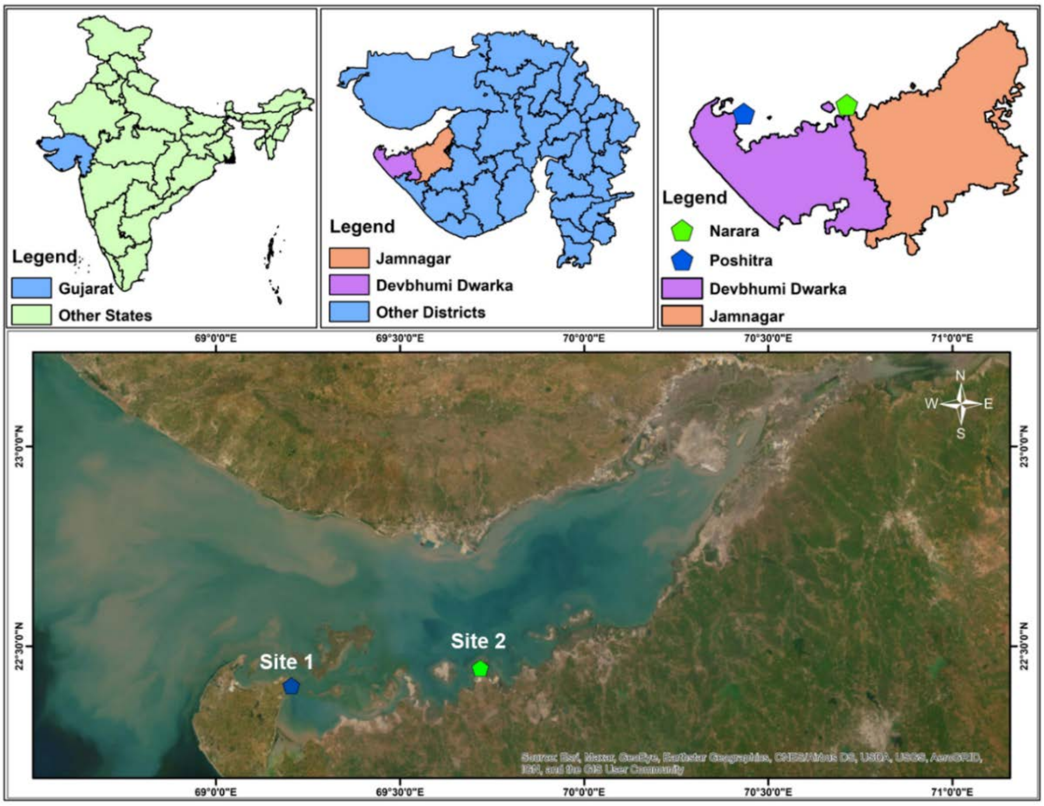

Figure 10: Selected study sites in Gulf of Kachchh

Poshitra (Site 1)

Poshitra is also known as the 'Crown of the Gulf of Kachchh' (Parasharya, 2008). At the northern coastal part of the Dwarka district, reef of Poshitra is situated which the entrance of the Gulf of Kachchh. Poshitra is located between 22°22.0' to 22°22.2' N latitude and 69°11.1' E to 69°12.5' E longitude in GoK. Its ecosystem mainly consists of mangroves, rocky shore, sandy reef flat and coral reefs. Eulittoral fringing reefs are mostly found in the vicinity of Poshitra near Laku Point, on the edge of the embayment, in a 100m wide region.

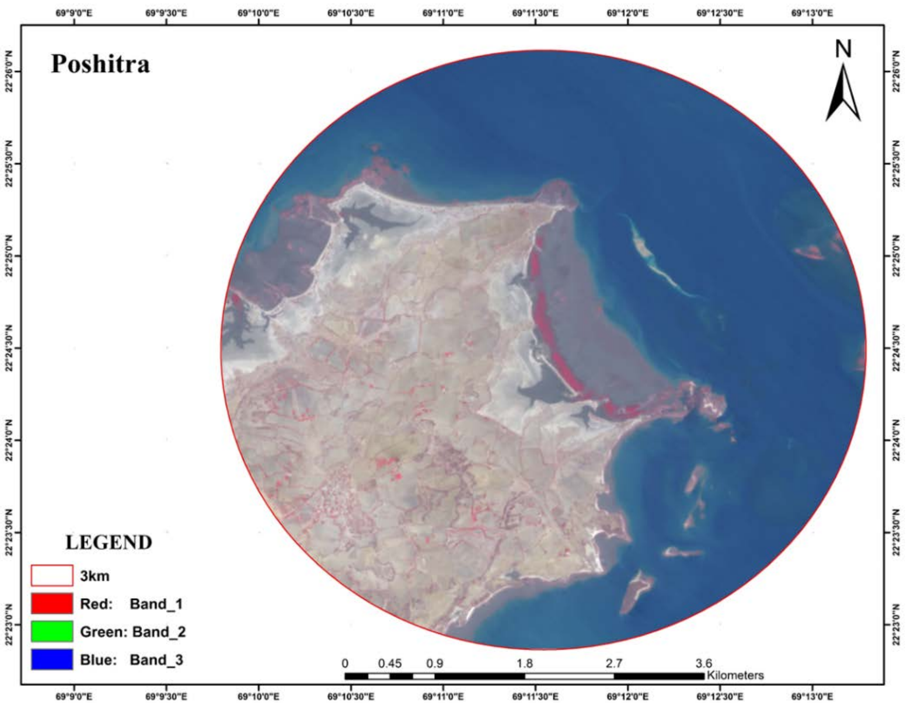

Figure 11: False Colour Composite Image of Poshitra

Narara (Site 2)

Narara is situated between Latitude 22°25.8'N to 22°28.3'N and Longitude 69°42.1'E to 69°40.7'E in southern coast of Gulf of Kachchh. Narara lies at the northern frontier of the Jamnagar district. It has the diverse ecosystems of mangroves, mudflats, sea weeds, algae and coral reefs. It is surrounded by other protected coral reef area like Kalubhar Island, Goose reef, Sri reef etc. Local communities also called it as a Narara Tapu or Narara Bet. It comes under Marine National Park & Sanctuary (MNP & S) and Narara is one of the tourist places where nature education camps have been organized by MNP & S to spread the awareness and importance of marine ecosystem in our lives. As there is no distinct demarcation of the mainland, Narara island has become a part of the mainland as a result of human invasion. In Narara, one can see living corals with a moderate distribution over the reef. According to Pandey *et al.,* (2010), here the live coral cover is around 4.93 percent, and the density of recruits of various genera found on the island is 21 recruits/100 m^2.

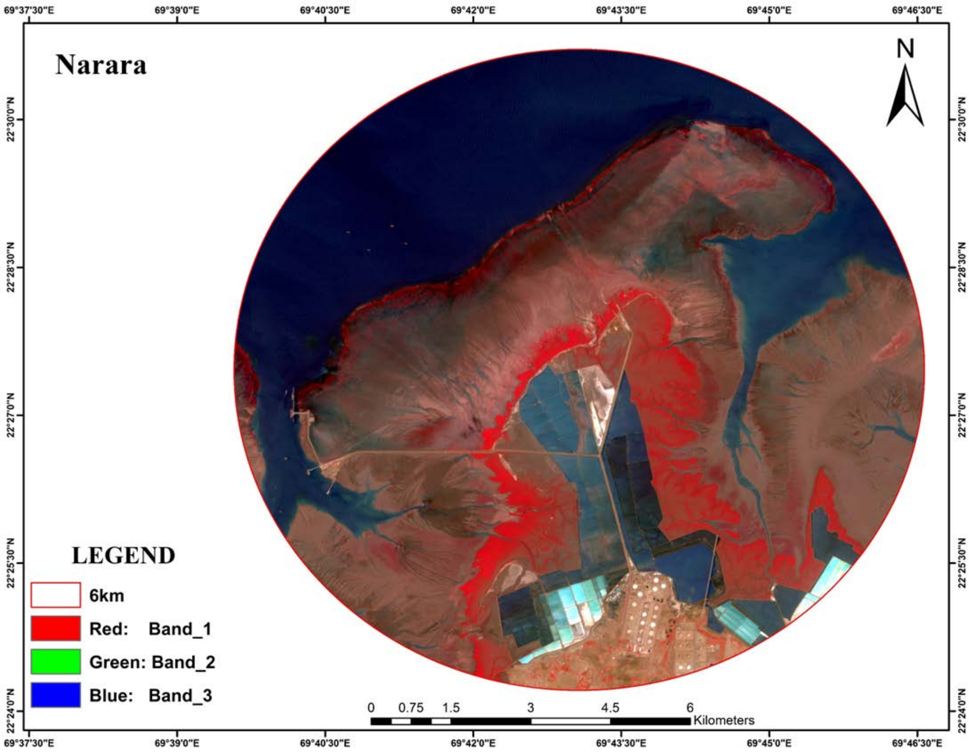

Figure 12: False Colour Composite Image of Narara

3.2 STUDY CONTEXT AND CONCEPTUAL FRAMEWORK

In the present study, in-situ data and satellite-based observations of some of the environmental variables named Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Turbidity, Total Suspended Matter (TSM), and Photosynthetically Available Radiance (PAR) have been considered to evaluate their effects on corals. The most commonly observed effect on corals has been seen as coral bleaching. Thus, the ultimate goal is to identify the conditions that are less vulnerable to stress using environmental data. Here, environmental characteristics and in situ bleaching survey data are used to predict coral reefs' sensitivity to bleaching. Figure (13) presents the general conceptual paradigm that this study used. The first phase entailed choosing factors that are known to affect coral bleaching and the adaptability of coral reef ecosystems. The primary variables were then obtained after the data had been retrieved and pre-processed. Coral bleaching observation data was employed as the response variable in a statistical analysis along with the primary variables and/or their corresponding derived parameters. Anomalies of the parameters were calculated to correlate their real-time and long-term effects on corals. Multi-linear regression method was used to generate the model and coral bleaching map for the entire area was created using a regression equation. The study's findings are meant to aid in the decision-support system for marine protected zones in order to preserve biodiversity.

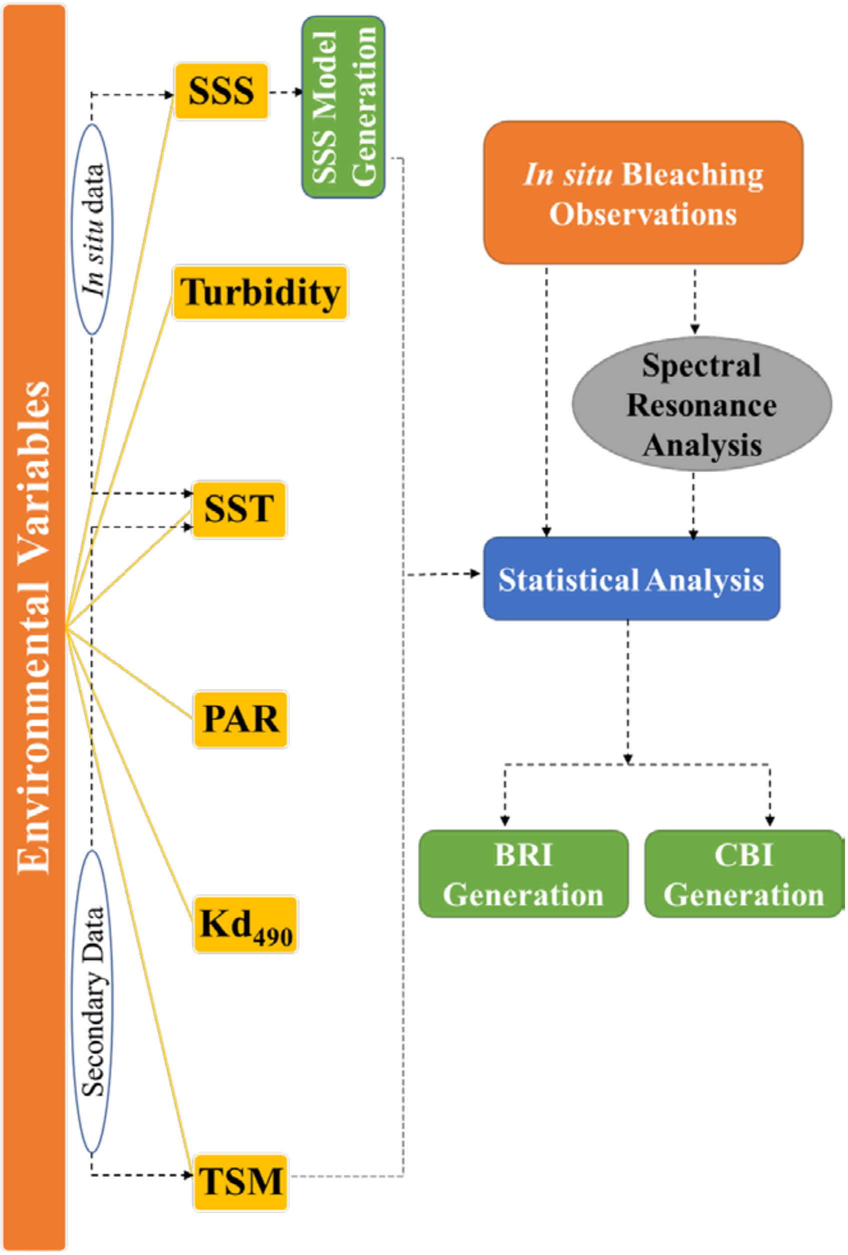

Figure 13: Conceptual paradigm for study context

3.3 IN-SITU DATA ANALYSIS

As corals fall into the category of schedule-1 of the Indian Wildlife Act 1972, required permissions were taken to conduct the field survey. Reefs of Narara and Poshitra islands were visited over the period of 03 years from 2019 to 2021. With the target to study the seasonal variations, field visits were conducted during the winter season (January) and summer seasons (March and June) of these years. Each field visit was planned following the daytime low tides to study the seasonal variations in the reef ecosystem.

The reefs were studied by random quadrant sampling method (Miller and Ambrose, 2000) for habitat characterization. Random sampling was done using a 1m^2 PVC frame (Figure 14). The number of coral colonies in each genus for every quadrant was recorded. Pictures of each quadrant were also taken for taxonomic identification of each coral colony later. GPS locations of each quadrant were also noted to generate the species diversity maps using satellite image processing software. With the aim to identify the stress of corals, the health conditions of each colony during the time of the visit were also recorded. For this, CoralWatch Coral Health Chart (Figure 18), a product of Queensland University, Australia was used.

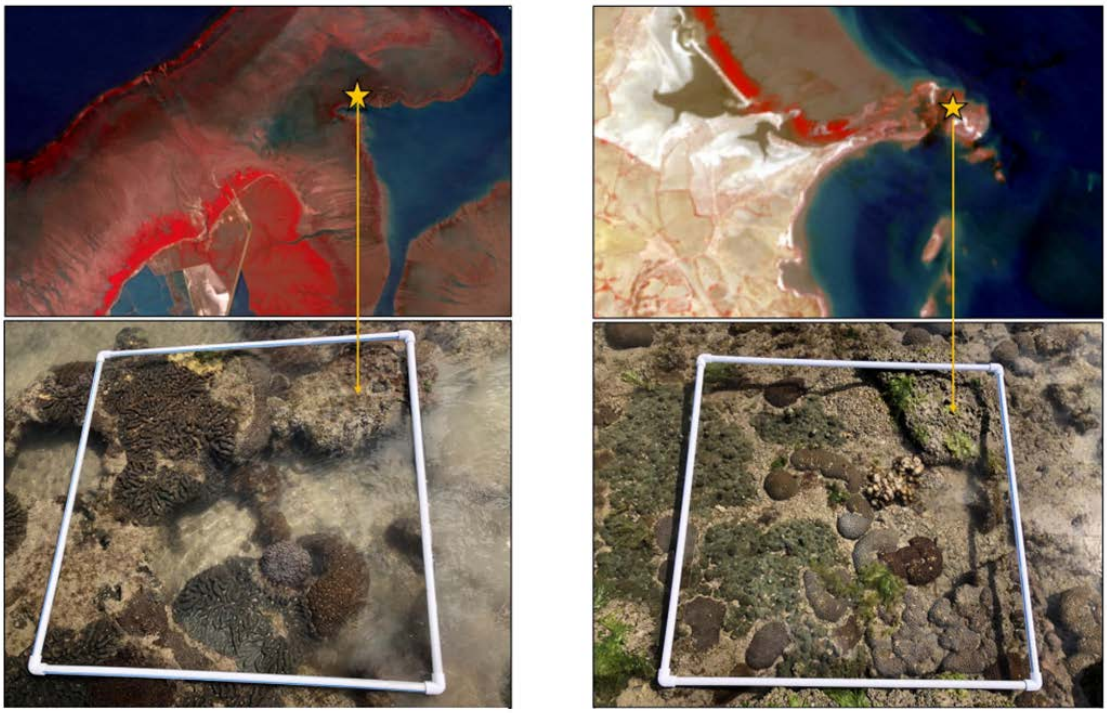

Figure 14: PVC frame for random sampling

Figure 15: In-Situ Data Collection and use of CoralWatch Coral Health Chart

Apart from health condition records, physio-chemical parameters like temperature, salinity and turbidity of the seawater were also collected along the reef from lower and mid-intertidal zones (Figure 16 & 17). The readings were collected with the help of nephelometer, refractometer and thermometer and all instruments were calibrated before each use.

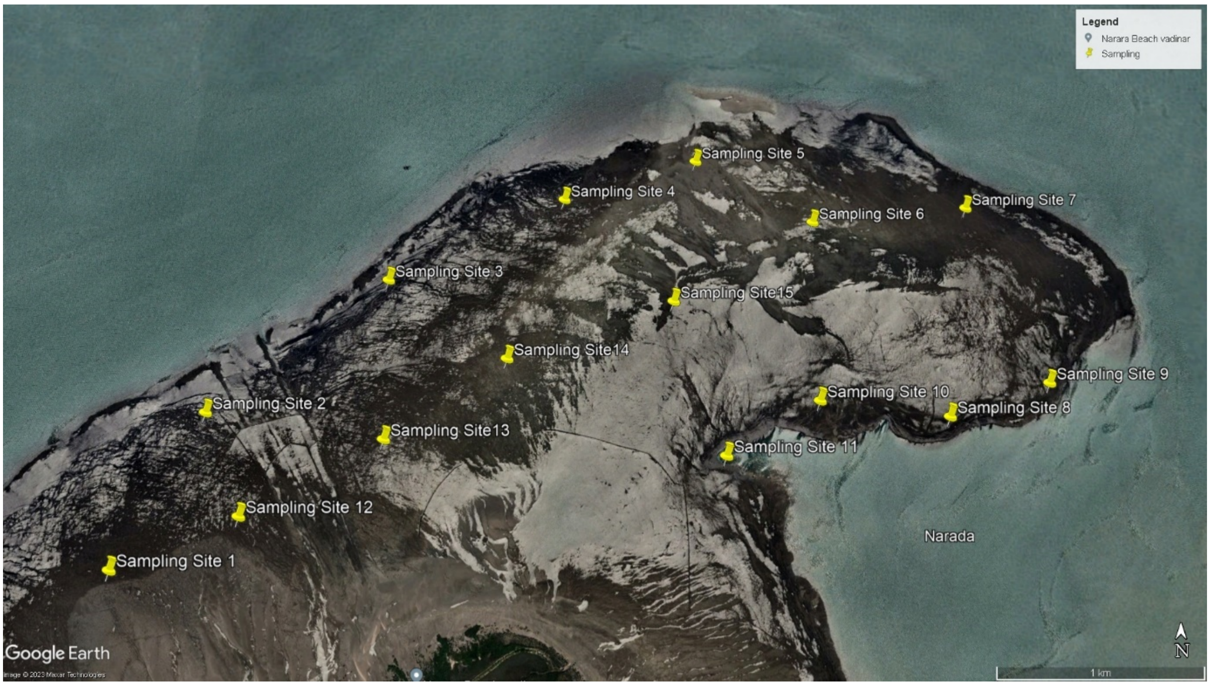

Figure 16: Sampling points from the site 1

Figure 17: Sampling points from the site 2

3.3.1 Computation of Bleaching Response Index (BRI) Using In-Situ Data

Idea behind the calculation of BRI was to calculate the genus level bleaching at each site. For this, the coral health of different species was assessed using Coral Health Chart. Here, all the observed coral colonies were segregated according to their genus and total number of coral colonies in each genus were calculated. By doing this, it will be helpful to calculate the BRI at genus level. Then, Lightest and darkest colours of each colony were recorded to generate the graphs based on the colour distribution and frequency of all the colonies observed in the study area. These graphs show the frequency of occurrence a particular genus of coral in a particular colour code category. Here, colour codes of health chart have been divided into four categories (Table 2).

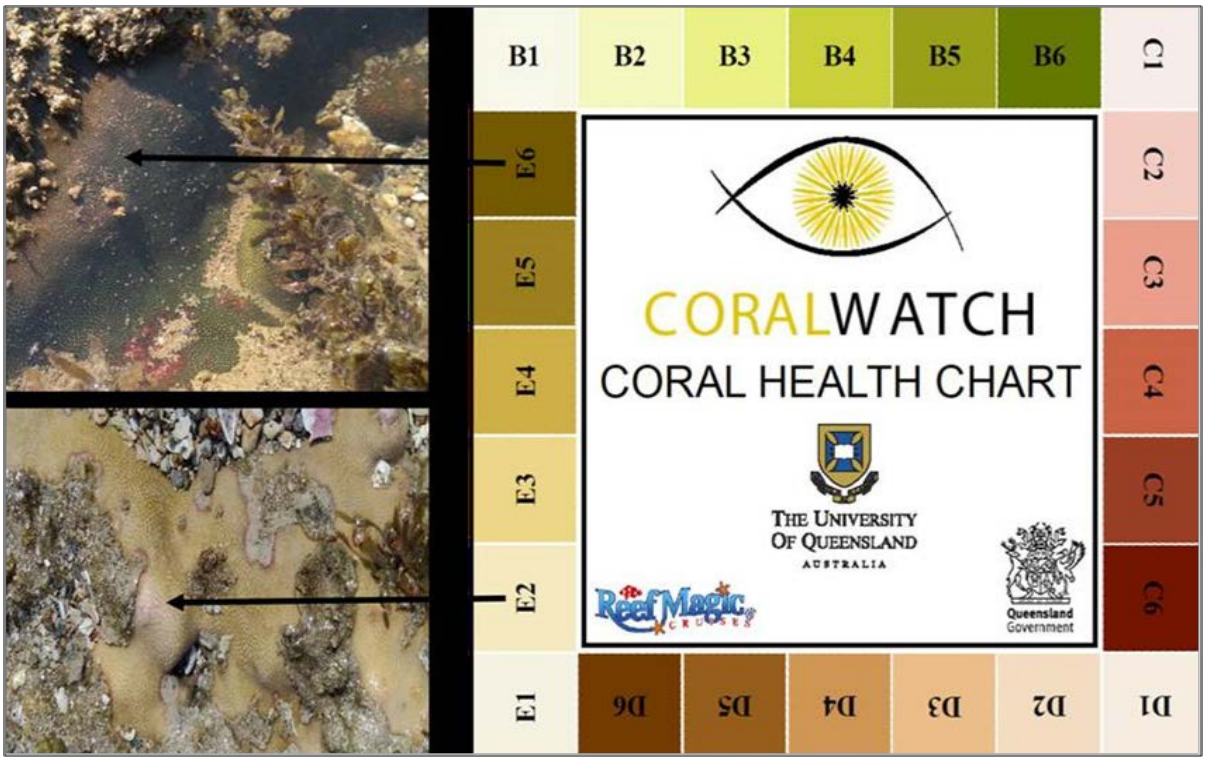

Figure 18: CoralWatch Coral Health Chart

While doing the field survey, totally bleached colonies and colonies which are almost bleached, has been considered as category 4. Similarly, colonies with moderate bleaching have been considered as category 3. During the study, it was observed that some of the fully grown healthy coral colonies have resembles with maximum colour score 4 to 6. That is why colour score 5 and 6 have been considered as healthy corals or no bleaching condition. In further calculations also, any values more than 4 has been considered as healthy corals. From these graphs bleaching percentage of each species were calculated for further statistical analysis. Furthermore, each of these categories were given the vector value to define the bleaching percentage class (Table 2) and values of category vector (C_i) are the weightage given to each category according to bleaching percentage. (Floros *et al.,* 2004).

$$C_i = (0, 0.3, 0.7, 1) \qquad (1)$$

Where, $i = 1, \ldots\ldots, M + 1$

Table 2: Bleaching Categories and their Weightages

Category	CoralWatch Colour Score	Bleaching Severity	Bleaching percentage	Percentage Weightage (C_i)
1	5-6	No Bleaching	0%	0
2	4	Partial Bleaching	1-30%	0.3
3	3	Moderate Bleaching	31-70%	0.7
4	1-2	Sever Bleaching	71-100%	1.0

Next step was to calculate the percentage of colonies in each category using the frequency data. These frequency percentage (W_i) then separated according to bleaching percentage class as shown in Table (2).

$$(W_i) = \frac{N_i}{\sum_{i=1}^{M} N_i} \times 100 \tag{2}$$

Where, N_i = Number of bleached corals in a particular category

Furthermore, vector of mean (b_i) of the bleaching categories was also calculated (Swain *et al.,* 2016) to relate the results of one category with all data.

$$b_i = \frac{C_i + C_{i+2}}{2} \tag{3}$$

Finally, to calculate the Bleaching Response Index, frequency percentage (W_i) were multiplied with the vector of mean (b_i).

$$\text{Bleaching Response Index}\,(BRI) = W_i b_i = \frac{N_i}{\sum_{i=1}^{M} N_i} \times 100 \times b_i \tag{4}$$

Where, W_i = percentage of bleaching colonies in category i

b_i = vector of mean

The percentage of BRI shows the resistibility of particular coral genus towards the bleaching conditions. Different level of resistibility for the BRI generated here, are divided into three categories which are shown in Table (3).

Table 3: Bleaching response categories of different Coral Genus

Bleaching Response	Bleaching Percentage
Resistible	0 - 30 %
Moderately Susceptible	31 – 70 %
Highly Susceptible	71 – 100 %

3.4 GIS DATA ANALYSIS

3.4.1 Study area Extraction

Open source QGIS software was used to extract the selected study area, downloaded satellite images of sentinel-2 were layer stacked with different band combinations by clicking on Raster in toolbar, using ‘Merge’ option in Miscellaneous.

- To create the AOI, shapefile of selected area was needed to clip the image by vector layer.
- In present study, shapefile of selected study areas was created by clicking on new shapefile layer option, shapefile of 3 km and 6 km buffer from the centre point of the area were generated by using Geoprocessing tool ‘Buffer’ in vector layer.

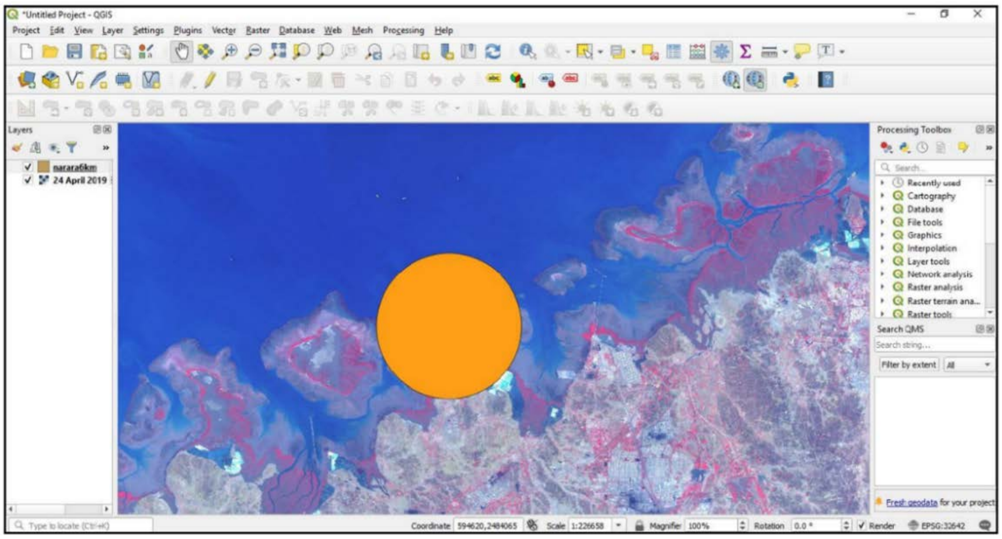

Figure 19: Extraction of Area of Interest

3.4.2 Coastal land use mapping from satellite image

With the use of free version Software of QGIS 3.10, on screen digitization of different land-use classes including coral reef and other coastal features was carried out to generate the Land-use Land-Cover maps of study area. Using the images of satellite Landsat-5 TM and Sentinel-2 MSI of the year 2010 and 2022, these maps were generated by the steps following.

- Use ‘Toggle Editing’ tool from toolbar to start editing and use polygon feature to make landuse/ landcover map.
- Give name and colour code to the polygons of different attributes in attribute table.

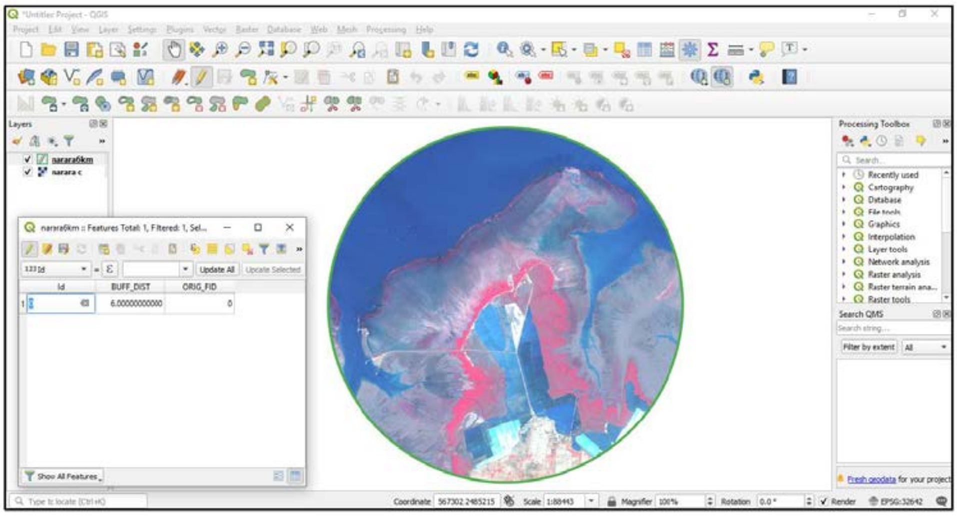

Figure 20: Clipped False colour composition Image

3.4.3 Generation of Inverse Distance Weighting (IDW) Index

Li & Heap (2008) stated that the IDW method is a simpler non-geo statistical methodology which calculates the attribute values of unsampled points using a linear combination of values of sampled points weighted by the inverse distance function from the point of interest to the sampled points with the help of formula:

$$\lambda_i = \frac{1/d_i^p}{\sum_{i=1}^{n} 1/d_i^p} \quad (5)$$

Where, d_i is the distance between two points x_0 and x_i, p = Power parameter, and the number of sampled points used for the estimation represented as n. Thus, creating distance between two sampled points demolish the weight where nearby sampling helps to get possible accurate results.

Here, ArcMap application was used to generate the maps of IDW index. In-Situ data like latitude, longitude and total number of coral species in each randomly sampled quadrate were used to generate the IDW maps.

3.5 SATELLITE DATA ANALYSIS

Secondary data of Sea Surface Temperature (SST), Photosynthetically Available Radiance (PAR) and Kd490 were downloaded from the National Oceanic and Atmospheric Administration (NOAA) website. Source and satellite information of these data are listed below in Table (4).

Table 4: Details of Secondary Data

Variable	Satellite	Sensor	Resolution	Date
Sea Surface Temperature (°C)	Analysed by NASA-JPL and NOAA ERD		1km	January, 2018 – December, 2021
Photosynthetically Available Radiance (Einstein m^{-2} day^{-1})	Aqua	MODIS	4km	January, 2018 – December, 2021
Total Suspended Matter (TSM)	Analysed by INCOIS		4km	January, 2018 – December, 2020
Kd490 (Diffuse attenuation coefficient K490, m^{-1})	Aqua	MODIS	4km	January, 2018 – December, 2021

1. Sea Surface Temperature (SST)

SST data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) website. The Multi-scale Ultra-high Resolution (MUR) Sea Surface Temperature (SST) Analyses is part of the NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program. Using wavelengths as basic functions in an ideal interpolation method on a global 0.01° grid, a Group for High Resolution Sea Surface Temperature (GHRSST) Level 4 sea surface temperature analysis was produced as a retrospective dataset (four-day latency) and near-real-time dataset (one day latency) at the JPL Physical Oceanography DAAC. The Advanced Very High-Resolution Radiometer (AVHRR), the NASA Advanced Microwave Scanning Radiometer-EOS, the JAXA Advanced Microwave Scanning Radiometer 2, the NASA Aqua and Terra platforms' Moderate Resolution Imaging Spectroradiometers (MODIS), the US Navy microwave WindSat radiometer, and other instruments' night time GHRSST L2P skin and subskin SST observations are all used in the version 4 Multiscale Ultrahigh Resolution (MUR) L4 analysis. The EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) High Latitude Processing Center's archives contain the ice concentration data, which is also used for an enhanced SST parameterization for the high latitudes. For some granules, the dataset additionally includes other variables, such as an SST anomaly calculated from a MUR climatology and the temporal separation between each pixel's nearest IR observation.

2. Photosynthetically Available Radiance (PAR)

PAR is defined as the quantum energy flux from the Sun in the spectral range 400-700 nm, or the visible wavelength range (Frouin *et al.,* 2000). PAR data collected in present study are the products of MODIS’s NPP (Net Primary Products) project. This dataset has Level 3, 4km, Science Quality (SQ) PAR data from NASA's Aqua Spacecraft. Measurements are gathered by the Moderate Resolution Imaging Spectroradiometer (MODIS) carried aboard the spacecraft.

3. Total Suspended Matter (TSM)

TSM data were downloaded from the Indian National Centre for Ocean Information Services (INCOIS) website. These are the 4km, Near Real Time (NRT) data. Analysis of aquatic component such as Chromophoric dissolved organic matter (CDOM) and total suspended matter (TSM) are part of Coastal and Oceanographic Research (SATCORE) programme. With the goal of conducting long-term measurements of bio-optical characteristics in the Indian coastal waters, INCOIS began organising the SATCORE programme for a five-year plan.

4. Kd490 (Diffuse attenuation coefficient)

The Wang *et al.,* (2009) approach, which weights distinct algorithms for clear open ocean and turbid coastal waters into a composite product, is used to generate diffuse attenuation coefficient. This method enhances accuracy in all oceanographic situations. Using in-situ information from the NASA SeaBASS database, this algorithm was created for the MODIS-Aqua instrument. Kd490 has only been validated for MODIS-Aqua thus far. Data from MODIS-Aqua Kd490 and in-situ Kd490 from the NASA SeaBASS database, which represent open ocean and some turbid coastal readings, were compared. With a mean ratio of 1.037, MODIS Kd490 data and in-situ observations were in reasonable agreement (Wang *et al.,* 2009).

Data of all of these environmental variables were downloaded in the .csv format. Using the IDW index method in Arc GIS, these data were extrapolated to generate the maps. Monthly and yearly anomalies of SST, PAR and TSM were calculated in excel to evaluate the long-term effects of these variables. For real-time effects, weekly anomalies were calculated to correlate their effects with the timings of field visit. Using the correlation method, both the real-time and long-term derived variables compared with the in-situ bleaching observation data to find out the derived variables that affected the most to the bleached corals of the reef. These data sets were also correlated with satellite derived bleaching model to make the future prediction. Since, satellite derived bleaching data were of 10m resolution, generated IDW images were further resample to 10m resolution for homogeneity in result calculations.

3.5.1 Sentinel-2 Image Analysis

The Sentinel-2 mission is part of the European Copernicus program from the European Space Agency (ESA), based on two identical satellites in the same orbit (Sentinel-2A and Sentinel-2B). According to Drusch *et al.,* (2012), both carry a substantial area of high-resolution Multispectral Imaging (MSI) with 13 spectral bands (Table 5). Since the launch of Sentinel-2A in 2015, and Sentinel-2B in 2017, these satellites have been in operation. Level-1C Top-Of-Atmosphere Reflectance (TOA) and Level-2A Bottom-Of-Atmosphere Reflectance (BOA) are two product versions of Sentinel-2 MSI. Satellite images of Level-2A Bottom-Of-Atmosphere Reflectance (BOA) ware used to carry out all the work related to image analysis. They were downloaded from the Copernicus' Sentinel Hub Browser website. All of these satellite images were level L2A images which are high resolution atmospheric corrected images.

Table 5: Sentinel-2 band characteristics.

(*) Band B10 is only available on Level-1C products

Band Number	Band Description	Central Wavelength (nm)	Resolution (m)
B1	Coastal aerosol	443	60
B2	Blue	490	10
B3	Green	560	10
B4	Red	665	10
B5	Vegetation red edge	705	20
B6	Vegetation red edge	740	20
B7	Vegetation red edge	783	20
B8	NIR	842	10
B8A	Vegetation red edge	865	20
B9	Water vapour	945	60
B10 (*)	SWIR - Cirrus	1375	60
B11	SWIR	1610	20
B12	SWIR	2190	20

Since, temporal availability of Sentinel-2 images is of 5 days over the GoK, difference between the time period of downloaded images and the in-situ data is around ± 7 days.

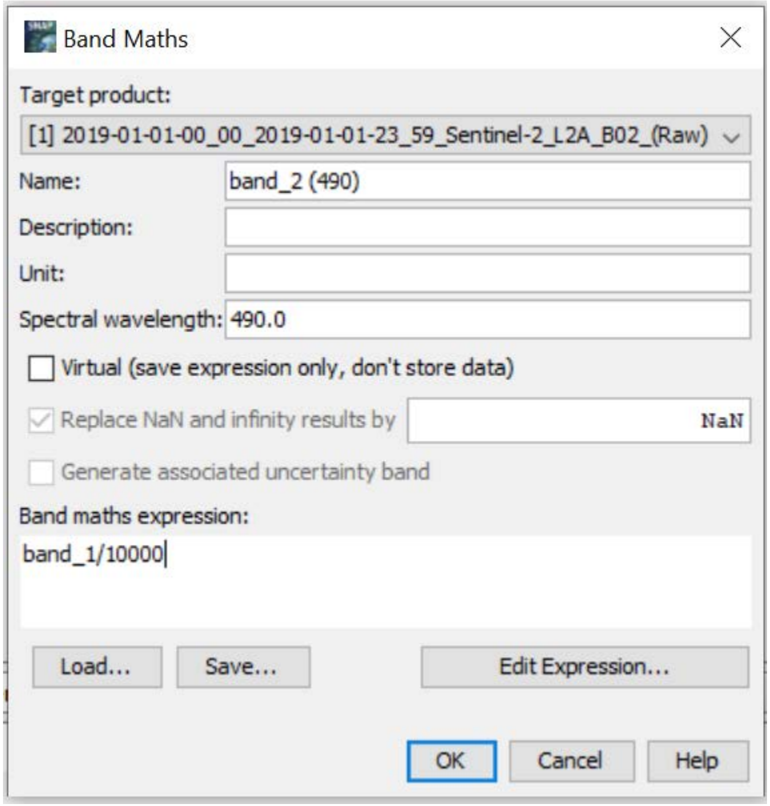

Figure 21: Reflectance calculation in Band Maths tool

Pixels of raw all L2A images contains the DN (Digital Number) values. In order to convert the DN values in reflectance (R_{rs}), following formula was used in band math tool of SNAP software (Figure 21).

$$\text{Reflectance } (R_{rs}) = \text{DN value}/10000 \quad (6)$$

All the bands in downloaded images of Level-2A Bottom-Of-Atmosphere Reflectance (BOA) is about 70m special resolution. Since, original resolution of these images is 10m, all bands were resampled to a 10m pixel size using Resample tool in Arc GIS software. After that, all the bands were composited into one single satellite image using Band Composite tool. All the further calculations and analysis were done using these resampled 10m resolution images.

3.5.2 Computation of Normalized Difference Turbidity Index (NDTI)

Normalized Difference Turbidity Index (NDTI) is a spectral index and it can only be generated after converting the DN values to the reflectance values. Thus, resampled and reflectance value generated satellite images were in order to generate the NDTI of both the Poshitra and Narara. NDTI is the ratio of red and green bands. The band combination formula for NDTI is:

$$\text{NDTI} = (\text{Red Band} - \text{Green Band}) \,/\, (\text{Red Band} + \text{Green Band}) \qquad (7)$$

The technique is used to generate qualitative turbidity levels as low, moderate and high turbid concentration based on the concentration of the concentration of particulate matters in water (Townshend and Justice, 1986).

3.6 STATISTICAL ANALYSIS

As there are more than two variables considered in this work, Multilinear Regression, Correlation, Histogram and Principal Component Analysis are the main statistical methods that have been incorporated to calculate the data. These statistical analyses have been used to calculate the Sea Surface Salinity (SSS) and remote sensing based coral bleaching index.

3.6.1 Model generation to calculate Sea Surface Salinity (SSS)

Since the secondary SSS data of the study were not available, SSS has been calculated using sentinel-2 data. With the help of in-situ data on salinity, the multilinear regression method has been used to calculate the SSS model.

For these, the latitude and longitude of in-situ data were recorded and saved in .csv version of excel. As, some of the prior studies have used different bands of visible rang to calculate the SSS, band 2(490), band 3(560) and band 4(665) of sentinel-2A have used in this work to estimate the SSS values. Then, using the geo locations of in-situ data, reflectance values of all the sampling points band 2, band 3 and band 4 were extracted from the SNAP software (Figure 22).

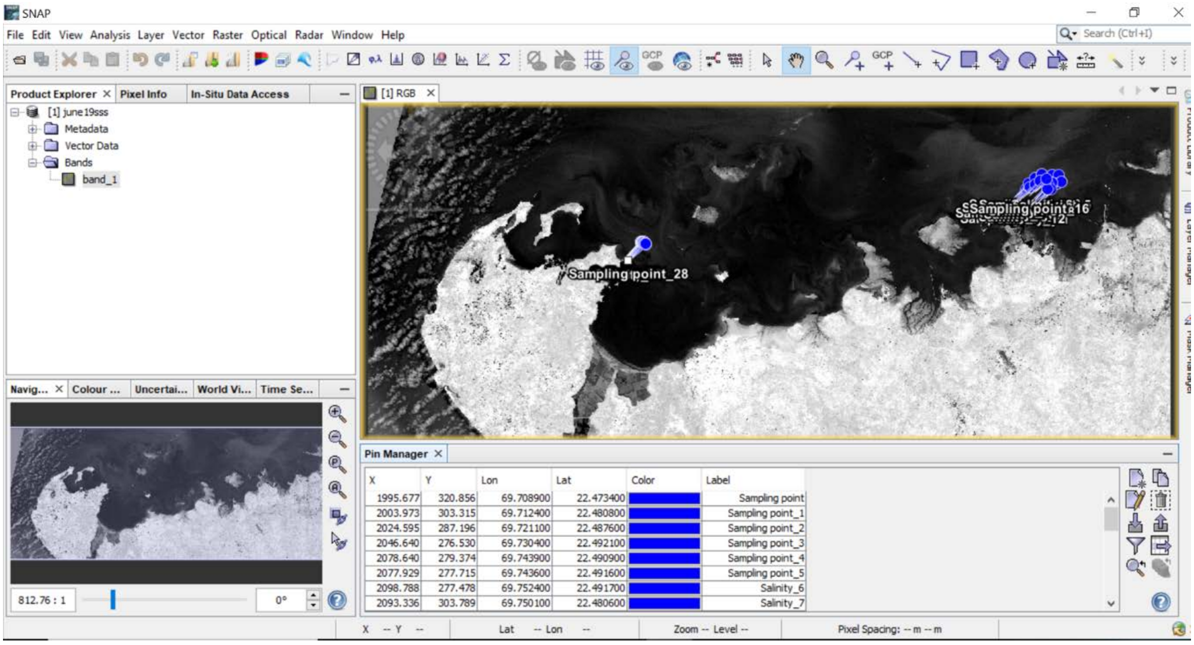

Figure 22: Extraction of reflectance value through SNAP software

Considering the in-situ as a dependant variable and reflectance in all three selected bands as an independent variable, multilinear regression was run using the formula (8) as shown below.

$$y_i = \beta_0 + \beta_1 (R_{rs}\ 492) + \beta_2 (R_{rs}\ 560) + \beta_3 (R_{rs}\ 665) \tag{8}$$

Where, i = number of observations

yi = dependent variable

β_0 = constant or the y-intercept

β_1, β_2, and β_3 = slope coefficients

Using this formula, raster images of real-time salinity of both the study sites were generated to correlate their effects with other real-time parameters and bleaching conditions.

3.6.2 Computation of Coral Bleaching Index (CBI) using satellite data

During the field visits, geo locations of bleaching conditions were recorded. As described in (Figure 14 & 15), different level of stress conditions was recorded using CoralWatch health chart. But, to quantify the bleaching using the spectral signatures, only colonies which falls in category (4) were selected as bleached corals. Moderate and partial bleach corals have not been selected because of spatial resolution.

Along with bleached corals, geo locations of healthy corals, sedimented corals and algae were also recorded. Using this all data at once, spectral signatures for each class were generated using SNAP software. Since, the satellite images were converted into 10 m resolution pixel size, geo locations of bleached corals were also divided into $10m^2$ grids, and percentage of bleached corals in each grid out of total grids were calculated for both the sites.

To generate the spectral signatures, total 10 band of sentinel-2 were selected to see the correlation of these classes in different band. The bands selected for these calculations are band 1, band 2, band 3, band 4, band 5, band 6, band 7, band 8, band 9 and band 8A. After extracting the values from different band, regression analysis was carried out and bands with P- value < 0.1 with 90% confidence interval were selected to generate CBI.

Same as formula (8), multilinear regression of selected bands was calculated using the percentage of bleaching in each pixel as dependent variable and bands with higher correlation as independent variables.

$$y_i=\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_p x_{ip} + e_i \tag{9}$$

Where, i = number of observations

yi = dependent variable

β_0 = constant or the y-intercept

β_p = slope coefficients

x_i = spectral reflectance of different correlated bands

e_i = random error term, also known as the residuals

Here, residuals of variables were also calculated to find the RMSE (Root Mean Square Error). The residual for each observation is the difference between the true value of the response variable (y_i) and the predicted value ($\hat{y}_i$).

$$Residual_i = y_i - \hat{y}_i \tag{10}$$

The standard deviation of the residuals is known as the root mean square error (RMSE). A lower RMSE value indicates that the regression model is more accurate.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y})^2} \tag{11}$$

As the main aim of computing CBI was to have the predicted value as near to the measured value as possible, this metric will be the one that will be concentrate on the most, using R-square and the P-value findings to better confirm the results. And using this regression model, CBI were calculated.

Following the same method, regression of different variables with CBI was calculated to find out the slope value for the generation of bleaching forecasting model.