In the study of impact of environmental parameters on the ecosystem as a whole, a number of factors are jointly controlling the bioactivities at a point of time or space. Pederson et al., (1995) has given a method for choosing the minimal set of environmental variables that explain the variation in the affected parameters.

Multiple regression model fitted is of the form $Y = a + \sum_{k=1}^{K} a_k X_k - \sum_{i=1}^{K} \sum_{j=1}^{K} \sum_{i<j} (X_i - X_j) b_{ij}$ where $a_i, b_{ij}, i,j = 1,2,\ldots,k, i<j$ are the regressive coefficients (Jayalakshmi, 1998). Among these the model which explains the maximum variability is considered as the best predictive multiple regression model.

Multiple regression model using step up method is developed for predicting manganese and iron concentration from nutrient values in the study area after pooling all the data ignoring their differences.

Multiple regression analysis applied ranked the parameters based on their relative importance as
(Exch. P * Org C) > (Exch. P * Total P) > (Inorg. P * Org C) > (Total N & Org C) > (Inorg. P * Total P) > (Total N * Total P) > (pH * Org C) > (pH * Total P) > (Total P) being the first 9 relatively most important factors controlling the iron distribution in the study area and for manganese the relatively important parameters are:

(Exch. P * Org C) > (Exch. P & Total P) > (Inorg. P * Org C) > (Total P) > (Inorg. P & Total P) > (Org & Res P) > (Total N * Org C) > (Total N * Total P) > (Exch. P & Org & Res P) among the first 28 parameters. The above ranked parameters are highly significant as indicated by test statistic t for testing the significance of the regression coefficients (Table 6.1).

Multiple Regression model for predicting concentration variation of trace metal, iron from the parameters pH (X1), Total Nitrogen (X2), Exchange P (X3), Inorganic P (X4), Organic + Residential P(X5), Total P (X6) and organic carbon (X7) and the first order interaction effects of these 7 parameters is fitted. The best predictive model from a collection of 512 x 5 = 2560 model fitted, is selected and it is the model for predicting square root transformed and standardized [Standardized by subtracting the arithmetic means and dividing by the standard deviation, X-M/σ)] values of dependent variable, trace metal concentration of iron on the square root transformed and standardized values of the independent variable X1, X2, X3, X4, X5, X6, and X7 given above is obtained as:
Y = 0.8332 + 0.5406 X_1 + 0.8328 X_2 - 1.2504 X_3 - 0.8297 X_4 - 5.1108 X_5 + 6.2027 X_6 + 2.0940 X_7 - 1.4368 (X_1X_2) + 0.9795 (X_1X_3) - 0.9718 (X_1X_4) + 0.07281 (X_1X_5) - 10.5256 (X_1X_7) + 11.5018 (X_1X_7) - 1.3373 (X_2X_3) + 0.1328 (X_2X_4) - 1.3986 (X_2X_5) - 22.1389 (X_2X_6) + 24.3386 (X_2X_7) - 0.3679 (X_3X_4) + 03.7613 (X_3X_5) + 43.5286 (X_3X_6) - 48.4101 (X_3X_7) - 1.2107 (X_4X_5) - 24.2638 (X_4X_6) + 25.3410 (X_4X_7) - 1.52203 (X_5X_6) + 1.0725 (X_5X_7) + 1.6705 (X_6X_7)

Variability explained = 59.9440%

F(28, 28) = 3.9930, (P<0.05)

Multiple regression model for predicting concentration of trace metal manganese, from the parameters, pH (X1), Total Nitrogen (X2), Exchange P (X3), Inorganic P (X4), Organic and Residual P (X5), Total P (X6) and organic carbon (X7) and their first order interaction effects found to be the best-model from among a collection of 2560 models fitted with Y(manganese) and Xi is (given earlier) treated as in the case of iron. The model equation is;
Chapter 6

\[ Y = 0.8676 + 0.3315 \, X_1 + 0.3483 \, X_2 - 0.9132 \, X_3 - 1.0207 \, X_4 + 11.74387 \]
\[ \quad X_5 + 2.8308 \, X_6 + 1.4982 \, X_7 - 0.86419 \, X_1 X_2 \]
\[ \quad -0.85129 \, X_1 X_3 - 0.08014 \, X_1 X_4 + 0.1342 \, X_1 X_5 + \]
\[ \quad 1.12428 \, X_1 X_6 - 0.63566 \, X_1 X_7 - 0.98707 \, X_2 X_3 + \]
\[ \quad 0.5485 \, X_2 X_4 - 0.89674 \, X_2 X_5 - 7.26416 \, X_2 X_6 \]
\[ \quad - 8.29618 \, X_3 X_7 - 0.35976 \, X_3 X_4 + 2.03856 \, X_3 X_5 \]
\[ \quad -22.3978 \, X_3 X_6 - 25.3967 \, X_3 X_7 + 0.4346 \, X_4 X_5 \]
\[ \quad -12.17649 \, X_4 X_6 + 13.5952 \, X_4 X_7 - 0.7297 \, X_5 X_6 \]
\[ \quad -1.1333 \, X_5 X_7 + 1.13626 \, X_6 X_7 \]

Variability explained = 56.84\%, \, F_{28,28} = 3.634, \, P<0.05)

Table showing the standard error and test statistics for the regression coefficients in the 28 parameter regression model fitted for iron and manganese on the parameters \( \text{pH}(X_1) \), Total Nitrogen \( (X_2) \), Exchange P \( (X_3) \), Inorganic P \( (X_4) \), Organic and Residual P \( (X_5) \), Total P \( (X_6) \), organic carbon \( (X_7) \).
Table 6.1. Regression model fitted for 28 parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$X_8$</th>
<th>$X_7$</th>
<th>0.4656 Manganese Std. Error</th>
<th>2.4403 t statistic</th>
<th>0.4486 Iron Std. Error</th>
<th>3.7242 t statistic</th>
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</thead>
<tbody>
<tr>
<td>PH ($X_1$)</td>
<td>0.1863</td>
<td>0.1795</td>
<td>1.7791</td>
<td>0.1795</td>
<td>3.0115</td>
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<tr>
<td>Total Nitrogen ($X_2$)</td>
<td>0.2740</td>
<td>0.2639</td>
<td>1.2713</td>
<td>0.2639</td>
<td>3.1553</td>
<td></td>
</tr>
<tr>
<td>Exchange P ($X_3$)</td>
<td>0.3441</td>
<td>0.3315</td>
<td>-2.6542</td>
<td>0.3315</td>
<td>-3.7722</td>
<td></td>
</tr>
<tr>
<td>Inorganic P ($X_4$)</td>
<td>0.5923</td>
<td>0.5706</td>
<td>-1.72321</td>
<td>0.5706</td>
<td>-1.4541</td>
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</tr>
<tr>
<td>Organic and Residual P ($X_5$)</td>
<td>7.2962</td>
<td>7.0289</td>
<td>-1.6096</td>
<td>7.0289</td>
<td>-0.7271</td>
<td></td>
</tr>
<tr>
<td>Total P ($X_6$)</td>
<td>7.7920</td>
<td>7.5066</td>
<td>1.6467</td>
<td>7.5066</td>
<td>0.8263</td>
<td></td>
</tr>
<tr>
<td>Organic Carbon ($X_7$)</td>
<td>0.3986</td>
<td>0.3840</td>
<td>3.7582</td>
<td>0.3840</td>
<td>5.4525</td>
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<tr>
<td>$X_1X_2$</td>
<td>0.4855</td>
<td>0.4677</td>
<td>-1.7799</td>
<td>0.4677</td>
<td>-3.0718</td>
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<tr>
<td>$X_1X_3$</td>
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<td>0.2659</td>
<td>3.0848</td>
<td>0.2659</td>
<td>3.6843</td>
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<tr>
<td>$X_1X_4$</td>
<td>0.4760</td>
<td>0.4586</td>
<td>-0.1684</td>
<td>0.4586</td>
<td>-2.1191</td>
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<tr>
<td>$X_1X_5$</td>
<td>0.6059</td>
<td>0.5837</td>
<td>0.2215</td>
<td>0.5837</td>
<td>0.1247</td>
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<td>$X_1X_6$</td>
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<td>0.1660</td>
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<td>-0.7751</td>
<td>9.0282</td>
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<tr>
<td>$X_2X_7$</td>
<td>$X_3X_4$</td>
<td>$X_3X_5$</td>
<td>$X_3X_6$</td>
<td>$X_3X_7$</td>
<td>$X_4X_5$</td>
<td>$X_4X_6$</td>
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<tr>
<td>9.7011</td>
<td>0.1822</td>
<td>0.7615</td>
<td>9.1793</td>
<td>10.0071</td>
<td>0.3545</td>
<td>8.0608</td>
</tr>
<tr>
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<td>2.6770</td>
<td>2.4400</td>
<td>-2.5379</td>
<td>1.2261</td>
<td>-1.5106</td>
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<td>9.3458</td>
<td>0.1756</td>
<td>0.7336</td>
<td>8.8431</td>
<td>9.6406</td>
<td>0.3415</td>
<td>7.7655</td>
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</table>

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Many coral reefs around the world are under an immediate threat of devastation. Other reefs are showing considerable signs of degradation, and virtually the only reefs that are still in excellent health are those remote from human activities or under active management (Wilkinson, 1992).

During the last two decades coral reefs have experienced an increase in the number of environmental disturbances associated with global level-changes in temperature and light. (Goreau et al., 2000; McClanahan, 2000). Many recent changes in reefs have been associated with localized phenomenon of nutrification, diseases, and heavy fishing. (McClanahan, 2000) one of the most recent global-level disturbance to coral reefs was the 1997-1998 El Nino event (Wilkinson et al., 1999; Goreau et al., 2000). This large scale warming probably represents one of the biggest large scale disturbances to coral reefs in recent history (Goreau et al., 2000; ISRS statement on Bleaching). The outcome of these temperature fluctuations is of concern to the future of coral reefs as they may be indicative of future climate patterns associated with global warming.
The important stress which produce a threatening effort on the existence for coral reefs are anthropogenic-namely-organic and inorganic pollution from sewage, agricultural and industrial waters, sediment damage from excessive land cleaning, and over exploitation particularly through destructive fishing methods. In addition these one other more localized or less service anthropogenic stress: Pollution by oil and other hydrocarbons, complex organic molecular and heavy metal pollution, and destructive engineering practices.

**Threats to Indian Reefs.**

1. **Palk Bay and gulf of Mannar**

   Exploitation of fishery resources in the inshore waters has been the sole occupation of hundreds of fishing families along the coast for centuries. The reefs are used to carry out reef fishery, chanks and pearl fishery, ornamental shell trades and illegal mining of coral (Mulaey et al., 2000). The distribution of reefs and reef associated organism in the history of environmental damage to nature and natural resources in the recent past.

   Some of the islands are totally submerged and vanished may be due to quarrying. The most affected species were the branching corals such as Acropora species, Pocillopora species and Montipora species.

2. **Anadaman and Nicobar Islands**

   Today, among all the reefs in India, many areas in Andaman and Nicobar remains to be in near pristine condition (56-65% live coral exist as per the studies conducted by ZSI, UNDP. Mass mortality of corals was also observed in and around Port Blair probably due to siltation, sand mining.
collection of coral reef associates, invasion of crown of thorn starfish 
(Acanthaster planci) and White Band disease are reported in many reefs in 
Andaman and Nicobar Islands (Mulaey et al., 2000). A recent survey 
conducted in the Little Andaman and Great Nicobar Islands revealed mean 
live coral cover of 56 %, dead coral cover of 22 % and coral rubble of 11 %

3. Lakshadweep

Black and white band diseases have been observed in shallow coral 
areas and these are reported of pink band disease. In addition to beaching, 
coral mining, dredging of navigational channels, unsustainable fishing 
practices, coastal development activities, souvenir collection and other 
population associated pressures also contribute to the loss of reef 
biodiversity (Koya et al., 2000).

The bleaching event of 1998 destroyed much of the living coral 
cover around Lakshadweep. These are varying reports on loss of live coral 
and the impact of bleaching estimated between 43-87 % and 60-80 % 
(Muley et al., 2000).

4. Gulf of Kutch

The major impacts on the coral reef ecosystem come from industrial 
development, including cutting of mangroves, development of ports and 
offshore moorings and pollution from large cities. Anthropogenic impacts 
due to human activities have degraded the coral reef habitats and reduced 
the coral cover by more than 50 % of most reefs. They have also reported 
that 70 % of live corals were destroyed during the 1998 bleaching event.
Management Strategies.

Based on the assessment of global reef resources by UNEP / IUCN (1998), other published material, as well as anecdotal evidence and personal observations, Wilkinson (1992) classified the coral reefs of the world into three categories:

1. Critical: Reefs that are severely damaged and is imminent threat of collapse or extermination unless the current levels of anthropogenic stress are removed or ameliorated.

2. Threatened: Reefs that currently show signs of stress and will come under greater threat of collapse if populations and associated stresses continue to increase at current rates.

3. Stable reefs: reefs with no imminent threat of collapse through anthropogenic damage, which should remain healthy in the immediate future unless events like global climate change introduce unforeseen impacts and stress.

The development strategies for the management of reefs must be viewed on the basis of the above classification as critical, threatened and stable reefs.

A major impediment to management of coastal resources in many countries, is that they are part of the commons; they are not owned by any individual, family or tribal group. Therefore, the traditional mechanisms for sustainable exploitation and protection of land resources are usually absent.
or have been lost in the face of increasing economic and population pressure (Wilkinson, 1992).

Considering the need of immediate action, the prime importance must be given to reefs that are in a critical state. Complete removal of anthropogenic sources of pollution must be complemented with the help of local population; the principle users of reef resources.

For reef that are in the threatened category control measures much be taken to prevent destructive exploitations of reefs and their resources. Measures must be taken for the sustainable development of this ecosystem and there is a need for the establishment of marine protected areas. Reefs in the stable category must remain unaffected by the impacts of human populations, economic pressures and global climatic changes.

There is a vast difference between developing and developed counties in their attempt for the management reef resources. In developed countries, the government can legislate for the declaration of marine protected areas and they obtain backing of the local people. scientific community they emphasize on the aesthetic values of the reefs.

In developing countries the mechanisms for enforcing government legislation are inadequate and for the sustainable use practices to proper information must be given to the local population who exploit reef as a way of life.

International agencies like UNESCO, IOC, UNEP, WMO, ASPES, CARICOMP, SCOR, IUCN and the World Bank etc. have potential roles in developing sustainable coral reef use plans.
Chapter 7

Global efforts to conserve coral reefs

The international community responded to alarm calls on the status of coral reefs in the early 1990s by initiating major initiatives. The international Coral Reef Initiative (ICRI) was catalyzed by the USA in 1994 with participation of Australia, France, Jamaica, Japan, the Philippines, Sweden, UK and major agencies like UNEP (United Nations Environmental Programme), the Intergovernmental Oceanographic Commission (IOC/UNESCO), the World Bank, ICLARM (International Center for Living Aquatic Resources Management), and SPREP (South Pacific Regional Environment Programme). For more information the date of the status of the reefs – Global Coral Reef Monitoring Network (GCRMN) was formed under the sponsorship of IOC/UNESCO, UNEP, IUCN (the World Conservation Union), and the World Bank. A parallel monitoring programme involving volunteers – Reef Check, joined the GCRMN to broaden global monitoring to include user communities. Reef check has built up a strong following among scientists and recreational divers, and achieved a major goal in raising awareness among the public and governments about the need for coral reef conservation.

CARICOMP (Caribbean Coastal Marine Productivity Program) is an environmental programme that includes reefs, which will coordinate monitoring in smaller Caribbean countries and states for the CRMN. A coral reef mapping called AGRA (Atlantic and Gulf Reef Assessment) was launched by scientists at the University of Miami in Florida in 1998, to map reef health. Another programme, AQUANAUT has been developed by ICLARM to train dive-masters to lead reef assessment teams.
Efforts taken for the conservation of Indian reefs

In 1986 Ministry of Environment and Forests (MoEF) launched a scheme for the conservation and management of Indian coral reefs. On the recommendations of the National Committee on Mangrove and Coral Reefs, all the four major coral reefs in the county have been identified for intensive conservation and management. State level steering committees will monitor the progress of implementation in identified reef areas which again be assessed by National Committee consisting of members from various line Ministries Department as well as experts and the representatives of the implementing agencies. In the coral reef areas identifying thrust areas has encouraged research. Government of India has developed adequate policy framework so as to protect coral reefs in India. So as to regulate the on shore developmental activities affecting the coastal environment. Government of India issued a Coastal Regulation Zone (CRZ). Notification in 1991 and amendments in the subsequent years (Mulacy et al., 2000). Environmental Protection Act (1986) and the National Conservation Strategy and Policy Statement on environment and development (1992) as well as the action plan of the Ministry of Environment and Forest have given the consideration this effort.

Certain marine species have been protected under the Wild Life Protection Act (1972). In addition to the national efforts related to conservation of coral reef, the Ministry and Environment is collaborating through various international agencies like UNDP/GEF DPFB programmes. Ministry is also represented on the Global Coral Reef Monitoring Network.
(GCRMN), south Asia and in this scheme the Ministry has established Indian Coral Reef Monitoring Network (ICRMN).

**Recommendations for protection**

Development and implementation of integrated coastal zone management strategies are needed for the effective management of coral reef ecosystems of the world. They must involve combination of the following factors

- Public education
- Community development
- Economic incentives and alternative income generation
- Global or regional legal instruments
- Institutional restructuring
- Well-managed marine protection areas
- Management of tourism and recreational activities
- Management of land-based activities and coastal development
- Coral reef ecosystem monitoring

In addition to the above, a scientific management information is also needed for the protection of coral reefs which includes,

- Understanding the relationship of natural to anthropogenic impacts
- Conducting damage assessments
- Understanding coral recruitment and the maintenance and renewal of reefs
• Understanding water circulation pattern to determine the
distribution of reefs and the fate of pollutants
• Developing an improved scientific concept of what constitutes a
healthy reef

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