1. General introduction:

Coral reefs are renowned for their spectacular diversity and have significant aesthetic and commercial values, particularly in relation to tourism and fisheries. About half of the world’s coastline is in the tropics and a third of them are coral reefs (Birkeland 1997). In terms of biodiversity, coral reefs are among earth’s most diverse ecosystems and are widely recognized as the ocean’s rain forest (Reaka-Kudla 1997). Their diversity is expected to be 3-5 times greater than previously recognised (Knowlton and Jackson 1994). Coral reefs are found in about 100 countries and sustain tens of millions of people in their daily protein requirement (Salvat 1992). The significance of the coral reefs fisheries is that they contribute nine million tones per year out of the total world fishery catch of 75-100 million tones (Smith 1978; Munro 1984). It has been estimated that the values of the coral reefs in the straits of Tiran and the Mollases reef off Florida Keys are $1,765 m^{-2} (Spurgeon 1992) and $2,833 m^{-2} (Mattson and DeFoor 1985) respectively, in terms of their potential as a source of novel and useful compounds to mankind. Any such estimation of the value of the coral reefs needs to include also the societal links of the ecosystem.

Coral reefs are being degraded on a global scale by a wide range of impacts, including mass bleaching events (Glynn 1993, 1996; Wilkinson 1998), diseases (Lessios et al. 1984; Aronson et al. 1998; Richardson 1998; Harvell et al. 1999), pollution (Pastorok & Bilyard 1985, Lapointe 1997) and several human activities (Munro 1983; Richmond 1993). Five major causes that alter the coral reefs are: 1) Storms and hurricanes, 2) Coral bleaching, 3) Diseases of reef organisms, 4) Outbreaks of coral predators like Acanthaster
plancii and 5) Mass mortality of the reef herbivores such as Diadema antillarum (Peters 1997). Natural chronic processes such as parrotfish grazing, disease and predation may result in greater cumulative mortality over a two years period than even a major hurricane impact (Bythell et al. 1993).

Disease is defined as any impairment (interruption, cessation, proliferation or other disorder) of vital body functions, systems or organs. Diseases are usually characterized either by: 1. an identifiable group of symptoms (observed anomalies indicative of disease) and/or 2. a recognizable etiologic or causal agent, and/or 3. consistent structural alterations such as developmental disorders, changes in cellular composition or morphology, and tumors (Peters 1997). Diseases can be divided into biotic and abiotic diseases. The parasitic relationship between a host and its symbionts eventually leads to the biotic disease of host. The biotic disease can be recognised when the presence of a pathogen results in a distinct deviation from normality as displayed by functional or structural deficit (Feingold 1988). When these pathogens are capable of causing or spreading disease in many individuals, they are called infectious agents. These infectious agents are either microparasites consisting bacteria, fungi, virus etc. or macroparasites like helminths and arthropods (Peters 1997). Exposure to abiotic factors beyond the tolerance of an organism can damage its body functions. This type of impairment is known as an abiotic disease (Peters and McCarty 1996). The abiotic environmental stress results in structural and functional body impairments. In any disease conditions, the biotic and abiotic factors are considered to be indistinguishable (Peters 1997).
"Diseases affect basic phenomena of life in oceans and coastal waters: for example, life span, life cycle, abundance, metabolic performance, nutritional requirements, growth, reproduction, competition, evolution, as well as organismic tolerances to natural and manmade environmental stress. In short, diseases are a major denominator of population dynamics" (Kinne 1980). Diseases can have effects that become manifested at the community level. Disease may either produce mortalities of individuals over varying periods of time (acute to chronic progressive mortalities) or alter the structure or function of an individual in such a manner so as to make it more susceptible to predation or environmental stress. The demise of even one species of coral reef may cause successional changes that alter the structure and function of a particular community and the reef ecosystem. There are several instances in which such successional changes have taken place. In coral reefs, for example, the mass mortality of the major herbivore, the Diadema antillarum together with hurricanes reduced the coral cover and the phase shift changed the coral dominated reef into algal dominated one (Done 1992). Replacement of Acropora sp. by Agaricia sp. in Belize (Aronson and Precht 1997) and by Porites sp. in Bahamas reefs (Greenstein et al. 1998) during mid 1980s to mid 1990s were not recorded in thousand year old geological cores. These results show that the diseases are recent phenomena (Harvell et al. 1999). Diseases of scleractinian corals is an important factor in changing the structure and function of coral-reef communities because loss of live tissue cover not only reduces the number of polyps producing new recruits, but also opens up new hard substratum space for settlement of sessile organisms (Peters 1997). As per the records, coral diseases have
been found in 54 different countries and 66% of the records are from Caribbean region that constitute only 8% of the world's total coral reef area (Green and Bruckner 2000). Coral diseases are a major threat to the coral reefs as the diseases are severe enough to eliminate a coral species from the ecosystem. *Acropora palmata* colonies were eliminated from the reef of the Virgin Island by the white band disease (WBD) (Gladfelter 1982). The black band disease (BBD) that spreads at an average rate of 3.5 cm day$^{-1}$ kills corals that grow approximately 2 cm per year (Rützler et al. 1983). Spread of the 'white plague II' was reported to affect reefs in a stretch of >400 km between 1995 and 1997 in Florida's reefs (Richardson 1998). Coral bleaching, an abiotic disease (Green and Bruckner 2000) in 1998 was the most geographically extensive and severe in recorded history (Wilkinson et al. 1999), causing significant mortality worldwide (Baird and Marshall 1998). The bleaching related mortality of some corals is likely to have been accelerated by opportunistic infections (Harvell et al. 1999). A bacterium has been believed to be an opportunistic infectious agent that could cause bleaching (Kushmaro et al. 1996). Tumours, neoplasia and hyperplasia have been recorded on corals throughout the world on several different species. 20% of the Caribbean coral colonies were reported to be having tumours (Morse et al. 1981).

Though disease related activity does not kill the entire colony, the exposure of the skeleton by the death of the polyps will increase the possibility of invasion by borers and grazers into the skeleton. Such bioeroders erode the CaCO$_3$ structures in a variety of ways and weaken the structure of the coral skeleton. The activity of these borers and grazers makes
the skeleton fragile and make them vulnerable to damages caused by simple mechanical forces (Glynn 1997). The Acropora corals collapsed because of the weakened skeletons that were caused by the intensified bioerosion after Acanthaster predation (Moran 1986; Birkland and Lucas 1990). Additionally, the tissue destruction may diminish the reproductive potential of coral colonies (Szmant-Froelich 1985) leading to diminished recruitment in already damaged reefs.

This alarming nature of diseases, if not prevented through proper management plan will significantly reduce the coral cover over a period of time. Undermining host resistance and facilitating pathogen transmission are the roles played by climate variability and human activity (Harvell et al. 1999). It is possible that the diseases or mortalities observed locally may actually signal a major epizootic in coastal habitats or even regions (Peters 1997). Therefore, understanding the epizootiology is very essential to formulate a management plan to deal with coral diseases.

Coral reefs are of three types. These are the fringing reefs, barrier reefs, and atolls (Guilcher 1988). Fringing reefs are those that grow along the shore. The barrier reefs are those similar to the fringing reef that grow parallel to the shore but physically isolated from the shore. Atolls were originally fringing or barrier reefs of islands. However, as the islands submerged, the corals kept growing towards the water surface, finally appearing in the shape of a ring enclosing a lagoon within. There are four major coral reefs in India, the Andaman & Nicobar Islands, Gulf of Mannar, Gulf of Kachch and Lakshadweep group of islands. Out of these, the Andaman & Nicobar Islands, Gulf of Mannar and Gulf of Kachch are fringing reefs, while the Lakshadweep
islands are the only atolls in India (Bakus 1994). The Lakshadweep archipelago is scattered some 200-400 kilometers west off the Kerala coast, with 36 coral islands and open reefs (Fig 1.1). These islands form the smallest of the Union Territories of India, and are the country's only atolls. They lie between 10-12° N and 71°40'-74° E in the Arabian Sea covering a land area of 32 sq. km including 12 atolls of which only 10 are inhabited. The ten inhabited islands are Andrott, Amini, Agatti, Bitra, Chetlat, Kadmath, Kalpeni, Kavaratti, Kiltan and Minicoy. The main islands are Kavarrati, Minicoy, and Amini. Kavaratti is the headquarters of these islands, while Bitra is the smallest of all, with a nominal population.

Corals are classified into hexacorals and octocorals based on cycle of mesenteries. The hexacorals are those that are having six or multiples of six mesenteries and octocorals have eight mesenteries. Hexacorals are hard corals and they form reefs. They have the dinoflagellate, Gymnodinium microadriaticum, widely called zooxanthellae inside its gastrodermal layers as cytobiont. The zooxanthellae and the coral polyps are in mutualistic relationship. The zooxanthellae obtain nitrogen and shelter from the host and in return the host gets photosynthate from the zooxanthellae. The presence of zooxanthellae enhances the calcification thereby contributing to the reef formation. The Octocorals include many soft corals and the sea fans, the gorgonians. The octocorals do not have the zooxanthellae associations. The diseases have been reported both in hexacorals and octocorals.

During a survey in Lakshadweep islands, a variety of factors were found causing total or partial mortality in corals. Some of the factors that were affecting the corals irrespective of species were bleaching, grazing of the
1.1. Lakshadweep group of islands showing Kavaratti Island, the study area
coral polyps by *Drupella* sp. and predation by the sea urchin, *Acanthaster plancii*, commonly called the 'crown-of-thorns'. Extensive partial mortality was observed in the dominant scleractinian coral species *Porites lutea* (Milne-Edwards & Haime). Most of these corals showing partial mortality were clearly distinguished by a pink line around the dead patch and the width of the line ranged from a few mm to a cm (Fig 1.2 & 1.3). Preliminary observations showed that the affected portions were colonised by a cyanobacterium and some fungal associations were found along with the polyps in both healthy and affected tissues.

1.1. Objectives: -

The objectives of the present study were:

1. To survey the diseases in corals in the Lakshadweep Islands for a period of three years,

2. To study the etiology of the pink-line syndrome in the coral *Porites lutea* and the response of the host polyps in the pink-line affected polyps at cellular and physiological levels,

3. To explore the role of biotic and abiotic factors around the polyps in the formation of pink-line in *P. lutea* colony.
1.2. Healthy colony of *P. lutea* (bar = 30 cm)

1.3. PLS-affected *P. lutea* (bar = 30 cm)