
Diseases of corals with particular reference to Indian reefs

J. Ravindran¹ and Chandralata Raghukumar²

¹National Institute of Oceanography, Regional Centre
Dr. Salim Ali Road, PB. No. 1913, Kochi

²National Institute of Oceanography, Dona Paula, Goa – 403 004

Abstract

Diseases are one of the factors that change the structure and functioning of coral-reef communities as they cause irreversible damage to the corals. Reports on coral diseases describe the etiological agents responsible for the disease and in a few cases, Koch's postulates have been proved. The report of Black Band Disease (BBD) among the corals of Caribbean reefs kick-started awareness on coral diseases among ecologists and naturalists leading to reports on the prevalence of new band diseases from other reefs. Outbreaks of several other diseases have also been reported from other reefs around the world. Other diseases reported so far are the White Band Disease (WBD), Rapid Wasting Syndrome (RWS), White Syndrome (WS), White Plaque, Shut Down reaction (SDR), Pink Line Syndrome (PLS) and bleaching in hexacorals. The Pink Line Syndrome (PLS) that affected *Porites lutea* colonies in Lakshadweep corals is the only disease in Indian reefs investigated extensively. It has been established that *Phormidium valderianum*, a cyanobacterium causes the PLS. Histological observations showed that the tissue was destroyed in PLS. The coral bleaching is the only abiotic disease known in the corals. Bleaching is triggered by anomalous high water temperature during summer in which the endosymbiont zooxanthellae are expelled from the coral tissue causing a break in symbiosis. Bleaching in the polluted or eutrophicated reefs delays or completely stops the recovery processes. This will be a major threat to the global coral reefs as forecast by the recent IPCC report. In octacorals, BBD, Red Band Disease (RBD) and *Aspergillois* are reported to be affecting the colonies. The *Aspergillois*, caused by the fungus *Aspergillus* sp. in gorgonians is the first coral disease in which the complete processes, such as entry and spread of the pathogen in the coral reef ecosystem, and the role of global change in the disease propagation, have been studied in detail.

Introduction

Coral reefs are among the earth's most diverse ecosystems in terms of biodiversity and are widely recognized as the ocean's rain forest (Reaka-Kudla, 1997). Coral reefs are being degraded on a global scale due to various threats. It is estimated that about 27% of the coral reefs were lost mainly due to the major bleaching episode in 1998 (AIMS, 2000). While bleaching episodes leave a chance for corals to recover, diseases of corals change the structure and functioning of coral-reef communities as they cause irreversible damage to the corals. Disease is defined as any impairment (interruption, cessation, proliferation, or other disorder) of vital body

functions, systems or organs (Peters, 1997). The importance of pathogens as regulators of coral populations in the tropical marine environments is poorly understood (Peters, 1988). A disease not only kills the coral colony, but also exposes the substratum from diseased corals for new recruits (Connell and Keough, 1985), but this may not be favorable in case of the eutrophicated waters where algal forms compete with new recruits for the space. Reports on coral diseases describe the presence of etiological agents in the affected colonies, and in few cases, they prove Koch's postulates. One of the most important, yet least understood, aspects of coral disease is the relationship between incidence of



disease and the environment. While it has been suggested that the recent increase in coral diseases is associated with a decline in reef environmental quality, very little quantitative work has been carried out in this area.

Global scenario

Some disease causing organisms of corals have been identified and mechanisms of mortality have been studied in some diseases, such as the Black Band Disease. However, many others remain poorly investigated. Infectious diseases in corals are different from genetic diseases found in them, such as unusual growth patterns resembling tumors, neoplasms or galls, which have been analogous to cancer (Goreau *et al.*, 1998). Often vectors spread pathogenic agents. For example, parrotfishes are believed to spread pathogens through oral mucus (Antonius, 1981a). Diseases can be classified as biotic and abiotic (Peters, 1997). In biotic diseases, various biological factors are responsible for the disease, while in abiotic diseases, abnormal features among environmental factors such as salinity, temperature, ultraviolet light, sedimentation or exposures to toxic chemicals may cause disorder. Biotic and abiotic factors are often interrelated. Physiological disorders often result from extreme environmental conditions. For example, corals expel zooxanthellae during times of anomaly in sea surface temperature (Bruno *et al.*, 2001). Many coral diseases are reported from all over the world in hexacorals and octocorals.

Diseases of scleractinian corals

The report on the Black Band Disease (BBD) in the corals of

Caribbean reefs kick started the awareness on coral diseases (Antonius, 1973) among ecologists and naturalists that brought in reports on new band diseases from other reefs. The name of the band diseases were specified using the prefix of the color of the band that appears in the affected colony. In general, most of the coral diseases were called 'band diseases'. The BBD is a major factor in decline of coral reefs in Florida reefs (Porter and Meier, 1992; Peters, 1993). The BBD contains a microbial consortium of microbes consisting mainly *Phormidium corallyticum*. In addition to this cyanobacterium, the band consists of numerous heterotrophic bacteria (Garrett and Ducklow, 1975), fungi (Ramos-Flores, 1983) and sulphur-reducing bacteria like *Desulfovibrio* and the sulphur oxidizer, *Beggiatoa* sp. (Ducklow and Mitchell, 1979; Antonius, 1981b). The main cause of the coral tissue mortality covered by *P. corallyticum* is due to sulphur accumulation underneath the band where the tissue is undergoing lysis.

White Band Disease (WBD) is a sharp advancing line where the distally located brown zooxanthellae bearing coral tissue is cleanly and completely removed from the skeleton, leaving a sharp white zone about 1 cm wide that grade proximally into algal successional stages (Gladfelter, 1982). The white band spreads from the basal region of the colony to the tip. No environmental factors that alter the speed of the white band are known. However recent reports indicate relationship between increase in SST and WBD. The white band causes substantial decrease in skeletal deposition. The affected tissues contain both gram



positive and gram-negative bacteria especially *Vibrio* spp. (Peters, 1984; Santavy and Peters, 1997; Ritchie and Smith, 1995, 1998). Koch's postulate experiments have yet to prove the role of this bacterium associated with the WBD in causing the disease.

The white plague was first reported from Florida Keys (Dustan, 1977) and subsequently from the Puerto Rico reefs (Bruckner and Bruckner, 1998). The affected colonies had no visible microbial flora on the surface of the colony. Microscopic studies revealed tissue degeneration and remnants of zooxanthellae, giving a bleached effect to the diseased colonies (Richardson *et al.*, 1998). A bacterium, *Sphingomonas* sp. was isolated from the diseased corals (Richardson *et al.*, 1998). The bacterium was later proved to be the pathogen through laboratory studies. This disease is transmissible and occurs seasonally (Richardson *et al.*, 1998).

The Rapid Wasting Syndrome (RWS) was reported from the Caribbean reefs. The disease leaves an eroded skeleton as it spreads laterally on the colony. The skeletal erosion may be as deep as 2 cm (Goreau *et al.*, 1998). A fungus and a ciliate were found on microscopic examination of the affected specimens (Cervino *et al.*, 1998).

White syndrome is the whitening of coral tissues that is thought to be a reaction to toxic chemicals leached from antifouling paintings of marine installations (Antonius and Riegl, 1997).

Shut Down Reaction (SDR) is a complete, spontaneous disintegration of the coral tissue, starting at the borderlines of the injury. Coenosarcular

tissue sloughs off in thick strands or blobs. The disease spreads along the branches in a ramose form, leaving denuded coral skeleton without a trace of tissue. The disease advancement on the affected colony is about 10-cm per hour. The advancement is a non-intermittent process, which does not stop before killing the entire colony. SDR is transmitted by contact. A piece of sloughed tissue triggers SDR within 5-10 min after a contact with another healthy colony.

Diseases of octocorals

The octocorals, similar to the scleractinian hexacorals, serve as hosts for numerous commensals, symbionts and parasites and also provide refuge for reef fish (Bayer, 1961). Among the octocorals, the diseases affected the gorgonians. Causes that result in the loss of tissue in gorgonians are detachment, fracture of the skeleton and overgrowth by fouling organisms (Yoshioka and Yoshioka, 1991). There are a few reports of disease-related mortality in gorgonians and other octocorals. Some of the diseases of gorgonians are described below.

BBD is known in the scleractinian corals caused by the cyanobacterium *Phormidium corallyticum* (Rützler and Santavy, 1983). The same pathogen, *P. corallyticum*, also causes black band disease in the gorgonia *Pseudopterogorgia acerosa* and *P. americana* (Feingold, 1988) and the mode of tissue loss in the gorgonians is similar to that of BBD in the scleractinians corals.

The RBD was reported to affect the octocoral *Gorgonia ventalina* in Belize (Rützler and Santavy, 1983).



RBD contains a cyanobacterium from the genus *Oscillatoria* (Richardson, 1992) in addition to other cyanobacteria. No particular cyanobacterium was observed to be associated with the diseased corals, and different species have been thought to be responsible in different locations (Santavy and Peters, 1996). RBD is similar to the BBD in its development of a microbial consortium in the mat, containing other cyanobacteria, the sulphur-oxidizing bacterium (*Beggiatoa*), heterotrophic bacteria and the nematode, *Araeolaimus* (Santavy and Peters, 1996).

The fungal disease in a gorgonian is the first coral disease in which the complete processes such as entry and spread of the pathogen in the coral reef ecosystem and the role of global change in the disease propagation have been studied. There has been a correlation between the decline in the Caribbean coral reef and sharp increase in the transport of the African dust over the western Atlantic (Shinn *et al.*, 2000). It is hypothesised that the prolonged drought in the highly grazed grasslands of the Sahel in Africa and the desiccation of the water bodies resulted in abundant fungal spores that are transported through the wind to the western Atlantic Ocean (Shinn *et al.*, 2000). This finding was further supported by a study that showed that there were no spores in the clear air (Weir *et al.*, 2000) and, therefore, the African wind was established as an effective carrier of fungal spores from African deserts to the western Atlantic region. *Gorgonia ventalina* and *G. flabellam* in the Caribbean suffer by the recession of rind tissues called coenenchyme, which is the outer

organic rich matrix containing the living polyps (Smith *et al.*, 1996). Only one species of fungus was found common to all the affected colonies. The fungus was identified to be *Aspergillus* sp. The 18S ribosomal RNA analysis showed that the fungus may be *A. fumigatus* (Smith *et al.*, 1996). The fungus was later identified as *Aspergillus sydowii* (Geiser *et al.*, 1998). Weir *et al.* (2000) successfully established Koch's postulates by inoculating the *A. sydowii* cultured from the spores collected from the African dust.

Indian scenario

Preliminary work on diseases of corals in Indian reefs was reported in Gulf of Kuchchh, Andaman and Lakshadweep corals (Ravindran *et al.*, 1999). Coral mortality due to various factors was discussed and a survey on the extent of coral bleaching in Andamans during mass bleaching episode in 1998 was reported. Subsequently, few reports appeared on a specific disease, pink line syndrome (PLS) that affected the *Porites lutea* colonies in Lakshadweep corals (Ravindran *et al.*, 2001; Ravindran and Raghukumar, 2002; Ravindran and Raghukumar, 2006 a, b). It has been established that the *Phormidium valderianum*, a cyanobacteria causes the PLS (Ravindran and Raghukumar, 2006b). Histological observations showed that the tissue was destroyed (Ravindran and Raghukumar, 2006a). There are observations on the skeletal deformation in the healthy looking coral colonies in the *P. lutea* colonies in Lakshadweep (Ravindran and Kannapiran - unpublished). Bacterial diversity associated with coral mucus in the colonies of Gulf of Mannar was



reported (Ganesh Babu *et al.*, 2004 and Kannapiran *et al.*, 2006). The diversity included *Vibrio*, *Pseudomonas*, *Micrococcus*, *Aeromonas*, *Bacillus*, *Arthrobacter* and *Flavobacterium*. A disease, 'pink line disease syndrome' in the Gulf of Mannar reefs was observed (Kumaraguru *et al.*, 2005). Nine types of coral diseases namely black band, white band, white plague, white spot, pink spot, black spot, yellow spot, yellow band and tumour were reported in Gulf of Mannar (Thinesh *et al.*, 2009).

Conclusion and recommendations

There is widespread degradation of coral reefs due to many factors including man-made and natural disasters. In addition to direct and indirect human influences, disease is another key factor killing the corals silently. As studies on diseases in corals indicates their presence in almost all parts of the global coral reefs, there is a need to understand the pathogenesis of corals with reference to local environmental conditions, host physiology and its susceptibility.

Terrestrial fungi reported in many studies show that they are more omnipresent and ecologically important than had been realized, besides their role as secondary invaders and known borers in corals. Endolithic fungi represent normal inhabitants of healthy corals. However, like opportunistic pathogens, these fungi may cause damage to environmentally stressed corals. Efforts must be made to prove their role as primary invaders wherever it is suspected to be the pathogen. The combination of terrestrial run off and nutrient enrichment with an intermittent supply of fungal and bacterial spores,

combined with warm El Nino conditions, sets the conditions rolling for environmental stress. The environmental conditions in triggering or supporting the disease process and the status of susceptibility of host for infection has to be explored scientifically. Concentration of stress indicator molecules such as Lipid peroxide (LPO), glutathione (GHO), ubiquitin, Hsp60 and Hsp70, small heat shock proteins, Superoxide dismutase (SOD) in corals with reference to environmental stressors need to be monitored to assess the level of stressors in the environment.

The knowledge generated through these investigations will contribute substantially to the drawing up of a management plan to conserve the corals.

References

1. A I M S , 2 0 0 0 . A v a i l a b l e <http://www.aims.gov.au/pages/research/coral-bleaching/scr2000/scr00gcrmn-report.html>
2. Antonius, 1973. New observations on coral destruction in reefs. (abstracts). *Proc. AMLC*, 10:3.
3. Antonius, 1981a. The "band" disease in coral reefs. *Proceedings of the Fourth International Coral Reef Symposium, Manila*, 2: 7-14.
4. Antonius, 1981b. Coral reef pathology: a review. *Proceedings of the Fourth International Coral Reef Symposium*, 2: 3-6.
5. Antonius and Riegl 1997. A possible link between coral diseases and a corallivorous snail (*Drupella cornus*) outbreak in the Red sea. *Atoll Res. Bull.*, 447: 1-9.
6. Bayer, F.M., 1961. The shallow-water Octocorallia of the west Indian region. *Stud Fuana Curacao Other Caribb Isl* 55.
7. Bruckner and Bruckner 1998. Rapid wasting disease pathogen or predator? *Science*, 279: 2023-2025.
8. Bruno, J.F., C.E. Ciddon, J.D. Witman, P.A. Colin and M.A. Toscano 2001. El Nino related coral bleaching in Palau, Western Coraline



- Island. *Coral Reefs*, 20: 127-136.
9. Cervino, J., T.J. Goreau, R.L. Hayes, L. Kayman, I. Nagelkerken, K. Patterson, J.W. Porter, G.W. Smith and C. Quirolo 1998. Coral disease. *Science*, 280: 499-500.
 10. Connel, J.H. and M.J. Keough 1985. Disturbance and patch dynamics of subtidal marine animals on hard substrata. In: The ecology of natural disturbances and patch dynamics (eds. S.T.A. Pickett and P.S. White), Academic Press, New York, pp. 125-151.
 11. Ducklow, H.W. and R. Mitchell 1979. Observations on naturally and artificially diseased tropical corals: scanning electron microscope study. *Microbial Ecology*, 5: 215-223.
 12. Dustan, P., 1977. Vitality of reef coral populations off Key Largo, Florida: recruitment and mortality. *Environ. Geol.*, 2: 51-58.
 13. Feingold, J.S., 1988. Ecological studies of a cyanobacterial infection on the Caribbean sea plume *Pseudopterogorgia acerosa* (Coelenterata: Octocorallia). *Proceedings of the Sixth International Coral Reef Symposium*, 3: 157-162.
 14. Ganesh Babu, T., P. Nithyan and E. Kannapiran, A. Veera Ravi and S. Karutha Pandian 2004. Molecular identification of bacteria associated with the coral reef ecosystem of Gulf of Mannar Marine Biosphere Reserve using 16S rRNA sequences. In : Proceedings of the National Seminar on New Frontiers in Marine Bioscience Research (Supplement) (eds. S.A.H. Abidi *et al.*), National Institute of Ocean Technology, Chennai, 2004, pp.47-53.
 15. Garret, P. and H. Ducklow 1975. Coral disease in Bermuda. *Nature*, 523: 349-350.
 16. Geiser, D.M., J.W. Taylor, K.B. Ritchie and G.W. Smith 1998. Causes of sea fan death in the West Indies. *Nature*, 394: 137-138.
 17. Gladfelter, W.B., 1982. White band disease in *Acropora palmate*: implications for the structure and growth of shallow reefs. *Bull. Mar. Sci.*, 32: 639-643.
 18. Goreau, T.J., J. Cervino, M. Goreau, R. Hayes M. Hayes, L. Richardson, G. Smith, K. De Mayer, I. Nagelkerken, J. Garzon-Ferrera, Diego Gil, Garrison Ginger, E.H. Williams, L.B. Williams, C. Quirolo, K. Patterson, J. Porter and K. Porter 1998. Rapid spread of diseases in Caribbean coral reefs 1998. *Revista de Biologica Tropical*, 46 : 157-171.
 19. Kannapiran, E., L. Kannan and Y. Thangaradou 2006. Ecology and distribution of heterotrophic bacteria from the coral reef environment of Gulf of Mannar Marine Biosphere Reserve. *J. Environ. Biol.* Accepted (Acceptance No: 29(1/2)).
 20. Kumaraguru, A.K., K. Jayakumar, J. Jerald Wilson and C.M. Ramakritinan 2005. Impact of the Tsunami of 26 December 2004 on the coral reef environment of Gulf of Mannar and Palk Bay in the south east coast of India. *Curr. Sci.*, 89: 1729-1741.
 21. Peters, E.C., 1984. A survey of cellular reactions to environmental stress and disease in Caribbean scleractinian corals. *Helgolander Meeresuntersuchungen*, 37: 113-137.
 22. Peters, E.C., 1988. Symbiosis to pathology: Are the roles of microorganisms as pathogens of coral reef organisms predictable from existing knowledge? 6th Int Coral Reef Symposium, Townsville (Australia) 1: 205-210, Peters 1993.
 23. Peters, E.C., 1993. Diseases of other invertebrate phyla: *Porifera*, *Cnidaria*, *Ctenophora*, *Annelida*, *Echinodermata*. In : Adv Fish Science, Pathology of Marine and Estuarine Organisms (ed. C.A. Fournie), CRC Press, pp. 393-449.
 24. Peters, E.C., 1997. Diseases of coral-reef organisms. In: Life and Death of Coral Reefs (ed. C. Birkeland), Chapman and Hall, London, pp. 114-136.
 25. Porter, J.W. and O.W. Meier 1992. Quantification of loss and change in Floridian reef coral populations. *American Zoologist*, 23: 625-640.
 26. Ramos-Flores, T., 1983. Lower marine fungus associated with black band disease in star corals (*Montastrea annularis*, E&S). *Biol. Bull.*, 165: 429-435.
 27. Ravindran, J. and C. Raghukumar 2002. Pink line syndrome (PLS) in the scleractinian coral *Porites lutea*. *Coral Reefs*, 21: 252.
 28. Ravindran, J. and C. Raghukumar 2006a. Histological observations on the scleractinian coral *Porites lutea* affected by pink-line syndrome (PLS). *Curr. Sci.*, 90: 720-724.
 29. Ravindran, J. and C. Raghukumar 2006b. Pink-line syndrome, a physiological crisis in the coral *Porites lutea*. *Mar. Biol.*, 149 :



- 347-356.
30. Ravindran, J., C. Raghukumar and R. Raghukumar 1999. Disease and stress induced mortality of corals in Indian reefs and observations on bleaching of corals in Andamans. *Curr. Sci.*, 76: 233-237.
 31. Ravindran, J., C. Raghukumar and R. Raghukumar 2001. Fungi in *Porites lutea*: association with healthy and diseased corals. *Diseases of Aquatic Organisms*, 47: 219-228.
 32. Reaka-Kudla, M.L., 1997. The global biodiversity of coral reefs: a comparison with rain forests. In: Biodiversity II: understanding and protecting our biological resources (eds. M.L. Reaka-Kudla, D.E. Wilson and E.O. Wilson), Joseph Henry Press, Washington, D.C. pp. 83-108.
 33. Richardson, L., 1992. Red band disease: a new cyanobacterial infestation of corals. *Proceedings of the American Academy of Underwater Sciences*, 10: 153-165.
 34. Richardson, L.L., W.M. Goldberg, R.G. Carlton and J.C. Halas 1998. Coral disease outbreak in the Florida keys. Plague type II. *Revista de Biologia Tropical*, 46: 187-198.
 35. Ritchie, K. and G. Smith 1995. Preferential carbon utilisation by surface bacterial communities from water mass, normal and white band diseased *Acropora cervicornis*. *Molecular Marine Biology and Biotechnology*, 4: 345-352.
 36. Ritchie, K. and G.W. Smith 1998. Type II. White band disease. *Revista de Biologica Tropical*, 46: 199-203.
 37. Rützler, K. and D.L. Santavy 1983. The black band disease of Atlantic reef corals. I. Description of the cyanophyte pathogen. *PSZNI Mar. Ecol.*, 4: 301-319.
 38. Santavy, D.L. and E.C. Peters 1996. Microbial pests: coral disease in the Western Atlantic. *Proc 8th Int Coral Reef Symp, Panama* 607-612.
 39. Santavy, D.L. and E.C. Peters 1997. Microbial pests: Coral disease in the western Atlantic. *Proceedings of the eighth International Coral Reef Symposium*, 1: 607-612.
 40. Shinn, E.A., G.A. Smith, J.M. Prospero, P. Betzer, M.L. Hayes, V. Garrison and R.T. Barber 2000. African dust and the demise of Caribbean Coral Reefs. *Geophysical Research Letters*, 27:3029-3032.
 41. Smith, G.W., L.D. Ives, I.A. Nagelkerken and K.B. Ritchie 1996. Caribbean seafan mortalities. *Nature*, 383: 487.
 42. Thinesh, T., G. Methews and J.K. Patterson Edward 2009. Coral disease prevalence in Mandapam group of islands, Gulf of Mannar, Southeastern India. *Indian J. Mar. Sci.*, 38 (4) : 444-450.
 43. Weir, J.R., V.H. Garrison, E.A. Shinn and G.W. Smith 2000. The relationship between Gorgonian coral (Cnidaria: Gorgonacea) diseases and African dust events. Abstracts, 9th Int. Coral Reef Symposium, Bali, Indonesia.
 44. Yoshioka, P.M. and B.B. Yoshioka 1991. A comparison of the survivorship and growth of shallow-water gorgonian species of Puerto Rico. *Mar. Ecol. Prog. Ser.*, 69: 253-260.

Pink-line Syndrome

