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Visualizing the scientific panorama of coral black band disease research: a bibliometric analysis

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Original Article

Abstract

Black band disease (BBD) is a relevant coral disease with wide global distribution. A remarkable number of studies exist regarding the etiological, microbiological, and ecological characteristics and extent of this widely studied disease. This bibliometric study comprehends the global literature published on BBD and aims to assess the research activities and trends on BBD using the Bibliometrix R-package. Authors, countries, institutions, core journals, thematic maps, and historic direct citation networks are analyzed. Assessment of author productivity summarizes that the majority of the scientific literature emanated from a smaller group of researchers, with 70% of authors contributing only single articles. The prominent collaboration in global BBD research is a trio between the USA, UK, and Australia. This indicates that research requires more focus and fostering in many developing countries, and this needs further active research collaborations with the developing countries. Co-occurrence networks and Co-citation networks outlined the most strongly related words, authors, papers, and sources. Thematic map reveals BBD research revolves around the basic themes such as "disease prevalence", but currently, interest has been shifted towards specialized themes like "microbial community". The focus of the majority of the researchers was on the abundance, prevalence, and spatio-temporal dynamics of BBD. Molecular and genetic level studies of the microbial communities that involve metagenomics approaches are ongoing and active. The specialized or niche themes such as microbial consortium, the shift in the microbiome, and the presence of quorum sensing inhibitors in this consortium are acquiring much interest. Analysis of BBD publications indicates that treatment methods, resistance, and coral immunity against BBD were some of the under-looked areas in the research. This bibliometric report provides a nutshell of the status of global BBD research that can act as a reference for and guidance to the coral scientists, research funders, and policymakers to tackle BBD.

Keywords: *Co-citation network, thematic map, Reference Publication Year (RPY) spectroscopy, Bradford's law, Lotka's law, historic direct citation network.*

Introduction

Globally, coral reefs face severe decline, and disease has been a significant contributor (Carpenter *et al.,* 2008; Rogers and Miller, 2013). BBD is the first disease ever to be reported in the corals (Antonius, 1973). It has widespread distribution as it has been reported throughout the Caribbean basin (Garrett and Ducklow, 1975; Edmunds, 1991), the Indo-Pacific (Antonius, 1985), including the Red Sea (Antonius, 1988), and subsequently in the Great Barrier Reef (GBR) (Dinsdale, 2002). Besides, BBD has been bestowed with a leading position in the top five topics addressed in the coral disease research literature underpinning its paramount role in the field of coral disease (Montilla *et al.,* 2019). The scientific literature concerning coral disease research might have been deprived of its prosperity in the absence of the well-studied BBD.

BBD is known to affect at least 42 of the Caribbean and 57 Indo-Pacific coral species (Sutherland *et al.,* 2004; Kaczmarsky, 2006). It is one of the major scleractinian coral diseases reported from the Wider Caribbean- "the so-called coral disease hotspot"–as compiled by the Global Coral Disease Database (Bruckner, 2009). The first quantitative study of BBD prevalence on the Great Barrier Reef (GBR) expanded the number of susceptible taxa to 21 species in 5 scleractinian families *viz.,* Acroporidae, Pocilloporidae, Faviidae, Poritidae, and Mussidae (Page and Willis, 2006). BBD was recorded from 6 scleractinian families (Acroporidae, Faviidae, Poritidae, Siderastreidae, Agariciidae, Fungiidae) and 13 scleractinian genera in the Maldivian Archipelago (Montano *et al.,* 2016). It is noteworthy that there are still recent first-time reports on BBD occurrence in some areas (Aeby *et al.,* 2015). The cause of the immense and inimitable popularity of BBD may be regarded as a vicious circle. The title of the first reported coral disease, the range of coral hosts inflicted (Green and Bruckner, 2000), and global distribution patterns can be deduced as the direct factor. Ironically, the indirect factor may be the same unrivaled popularity.

Bibliometrics, the application of mathematics and statistical methods to books and other media of communication (Pritchard, 1969), serves as a quantitative analysis tool for written communications. It is functionally different from the traditional review of literature as this focuses more on the statistical data on literature rather than a conventional descriptive history of the related research topic or field (Ellegaard and Wallin, 2015). This method of evaluating the producers, processes, and evolution of research using research publications as a proxy for research is expressed with the aid of bibliometric indicators that include quantity, performance, and structural indicators (Durieux and Gevenois, 2010). Bibliometric applications may be broadly constituted under three main categories namely methodology research, scientific disciplines, and science policy. Bibliometric analyses have acquired progressive importance in the field of biomedical research (Thompson and Walker, 2015). Numerous bibliometric studies concerning popular diseases imply that visualizing the huge array of published literature through the eyes of bibliometric indicators will provide a comprehensive outlook of the research on that disease (Chiu *et al.,* 2004; Narotsky *et al.,* 2012; Delwiche, 2018). Coral disease research has flourished in the past decades and has accrued a considerable amount of literature. Considering the potential of bibliometrics, an attempt is made to explore the scientific realm of coral disease research. The apparent prominence of BBD accounted for the reason behind opting for this coral disease for such an approach. The current study aims to decipher the statistics of research progression, characterize the knowledge domain, scientific productivity, examining the research front, and examining the nature of the collaborations thereby comprehending the global black band disease research.

Material and methods

Data Collection

Data related to BBD from scientific publications indexed at Elsevier's SCOPUS Collection, and Clarivate Analytics Web of Science were collected. The search was made on December 31, 2018, covering the years 1983 to 2018. The advance search mode was used, which covers title, abstract, and keywords. In these databases, other than the authors' keywords (DE) which are provided by the original authors, database editors have created a separate list for the keywords called keywords plus (ID), which includes the relevant words reviewing the article's reference list and thus broadening the search results. The search query given was [(("black" AND "band" AND "disease") OR ("black band disease") AND "coral")] and Document Types: (Article), Indexes = SCI-EXPANDED, Timespan = 1983– 2018. The search results were downloaded in BibTeX format and processed in the R environment. An aggregate of 157 documents from over 56 sources (including journals and books) indexed on Elsevier's Scopus and Clarivate Analytics Web of Science was retrieved from 1983-2018, and data was used for the present analysis.

Data analysis

The data were analyzed using the 'bioblioshiny' package (Aria and Cuccurulo, 2017) of the statistical software R 3.5.2 (R Core Team, 2019). This software performs the analysis at descriptive and structural levels (conceptual, intellectual, and social structures). Analysis at a descriptive level portrays some snapshots about the annual research development, the most productive authors, papers, and countries. Frequency polygon charts of annual scientific production; bar charts of most productive authors; and vector maps with the varying colored symbology of country scientific production have been used to make a comprehensive description of the data. The conceptual structural analysis employs keyword co-occurrence networks and thematic maps to unveil the links between concepts. Cocitation networks (whose nodes represent authors, papers, or journals) were used to understand the intellectual structure of the research field (Aria and Cuccurulo, 2017). The historiography, a historical direct citation network, which draws the abstract linkages in chronological succession, has also been built that provides further insights into the intellectual domain of BBD research. Data visualization through networks showing collaborations among countries, authors, and institutions involved in BBD research was utilized to analyze the social structure.

Results and discussion

Typology of documents

An aggregate of 157 documents from over 56 sources (including journals and books) indexed were retrieved from 1983-2018. The retrieved documents constituted four different types with an average citation of 35.32 per document. The retrieved documents consisted of 1136 keywords that come under the keyword plus (ID) category and 359 keywords that fall under the Author's Keywords (DE) category (Table 1). The majority of documents were research articles (147); followed by conference papers (7), articles in press (2), and notes (1).

Table 1. Main information and Typology of Document

Description	Results
Documents	157
Sources (Journals, Books, etc.)	56
Keywords Plus (ID)	1136
Author's Keywords (DE)	359
Period	1983–2018
Average citations per documents	35.32
Authors	345
Author Appearances	624
Authors of single-authored documents	6
Authors of multi-authored documents	339
Single-authored documents	8
Documents per Author	0.455
Authors per Document	2.2
Co-Authors per Documents	3.97
Collaboration Index	2.28
Document types	
ARTICLE	147
ARTICLE IN PRESS	2
CONFERENCE PAPER	7
NOTE	1

Annual scientific production and growth of publications

The annual scientific production shows an increasing trend (Fig.1) during the study period. The number of articles increased during 2006-2018, with approximately 79% of documents published in these years. The highest number of documents retrieved belonged to the year 2009 with 15 publications. In 1983, three publications were identified compared to the peak number of publications in 2009 that show an apparent growth in the publication of articles.

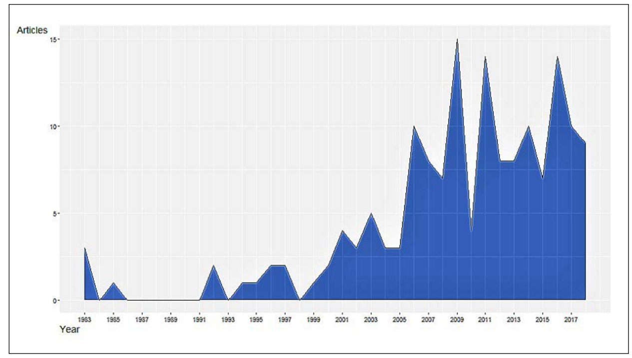

Fig. 1. Annual scientific production of BBD articles

Productivity of countries

Overall, 28 countries were represented across the study period, with the USA producing a maximum number of publications (146), followed by Australia (86), Israel (31), India (23), the UK (19), Indonesia (10) and so on (Fig. 2). The countries with poor scientific productions in BBD include Thailand, Belgium, Philippines, Portugal, and Guam, contributing only one article each. The USA remains the most cited country with a total citation of 3033 and an average article citation of 50.5 (Fig. 3). Even though the scientific production of the UK is less than Israel and India, it has much higher citations than these countries, with an average citation of 83.5. With total citations of 84 articles, Saudi Arabia is in a higher position than India and Indonesia despite

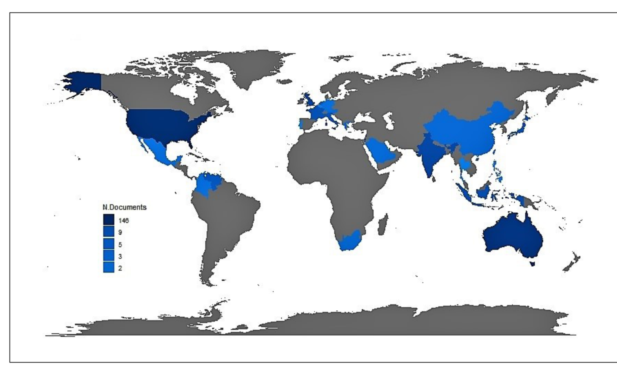

Fig. 2. Country Scientific Production

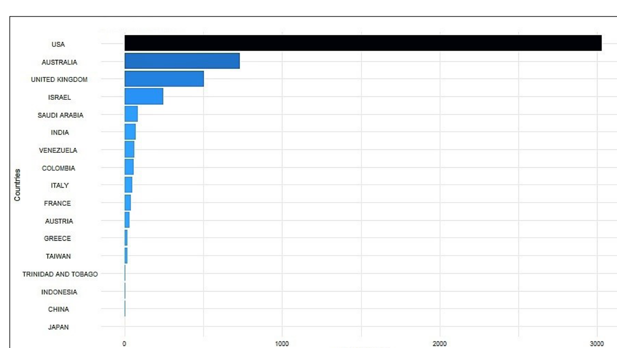

Fig. 3. Most cited countries

lesser scientific production. Country collaboration analysis reveals the presence of 7 different clusters. The most significant cluster includes the USA, Saudi, Netherlands, Philippines, Dominica, China, and Guam (Fig. 4). Australia showed collaboration with nine countries (Austria, Belgium, Germany, Israel, Netherlands,

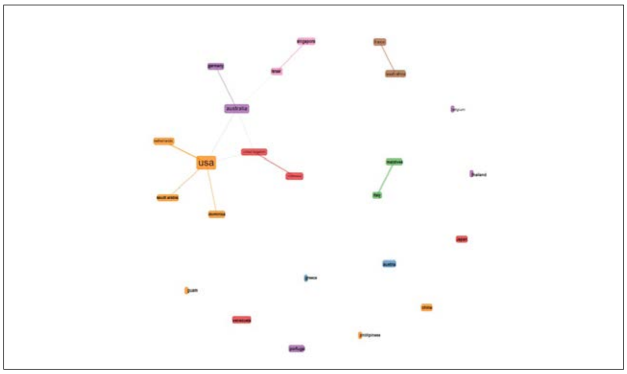

Fig. 4. Collaboration of Countries

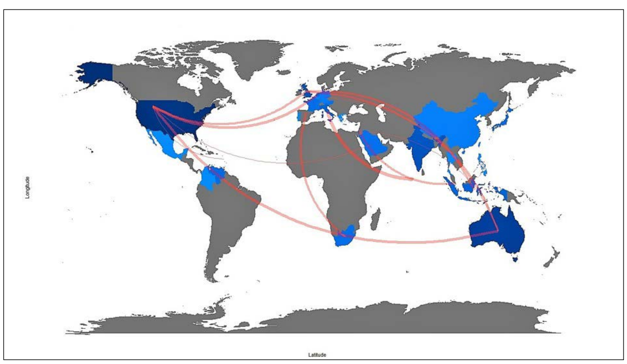

Fig. 5. Country Collaboration Map

Portugal, Thailand, and the United Kingdom). The USA showed collaboration with ten countries and the UK with five countries. It is also interesting to note that Italy and Maldives showed the highest collaboration (Fig. 5).

Authorship analysis

Analysis of data reveals the involvement of 342 authors in the publication of the retrieved documents (enabling overlap increasing the number of appearances of authors to 624), providing an average of 2.18 authors per document. Approximately 98% (339) were part of multi-authored documents, and only a minor group of roughly 2% (8) were individuals having single-authored publications. The mean of documents per author was 0.455 (Table 1). The top twenty most relevant authors are given in (Fig.6). The most prolific author was Laurie L. Richardson, with 33 articles in her credits. Willis B. is ranked second with 17 articles. The mean frequency of the top ten productive authors is 11. The author's scientific productivity assessed through Lotka's law indicates a considerably high number of authors (70%) have contributed only single publications (Fig. 7). The number of authors and the corresponding number of articles contributed

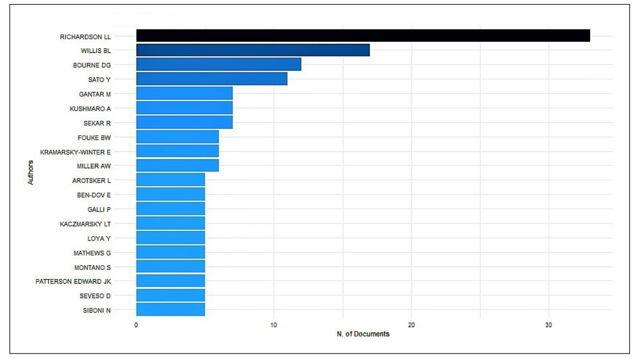

Fig. 6. Most relevant author

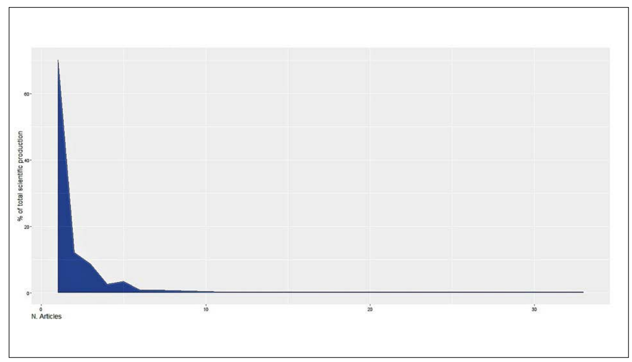

Fig. 7. Author's Scientific productivity

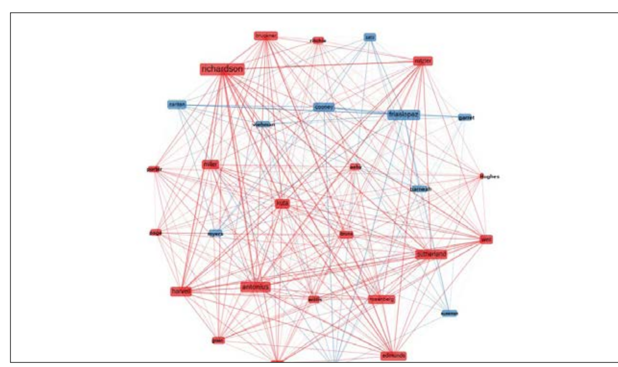

Fig. 8. Co-citation Network of Authors

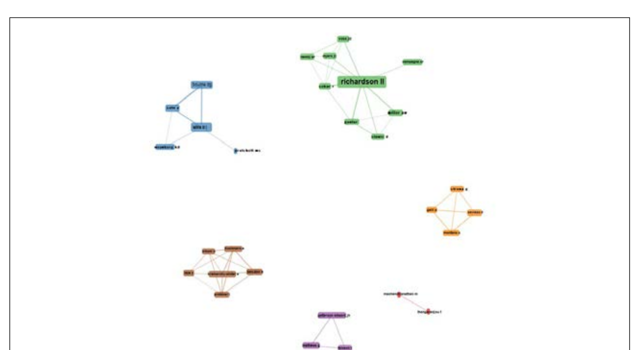

Fig. 9. Collaboration of Authors

by them are indexed in (Table 2). Networks regarding the co-citation of authors possess two clusters. Richardson, Sutherland, Antonius, Edmunds. Harvell, Rutzler, Bruckner, *etc.*, are cited together frequently compared to the co-citation of Friaz Lopez, Cooney, Carlton, Sato, *etc* (Fig.8). Author collaboration networks had six distinct clusters. The largest collaboration included the cooperation between nine authors, namely Richardson, Campagna, Stanićd, Gantar M, Miller A. W., Sekar R., Myers J. L. l, Voss J. D. and Remily E. R. (Fig. 9).

Table 2. Number of authors and corresponding number of their articles

No. of Articles	No. of Authors	Frequency
1	242	0.7014493
2	42	0.1217391
3	30	0.0869565
4	9	0.0260870
5	12	0.0347826
6	3	0.0086957
7	3	0.0086957
11	1	0.0028986
12	1	0.0028986
17	1	0.0028986
33	1	0.0028986

Productivity of sources

The retrieved documents belonged to 57 different journals, but the top ten journals accounted for 56%. The most relevant sources are identified based on the number of documents contributed by each source. Diseases of aquatic organisms are the most relevant journal, followed by the Coral Reef, Environmental Microbiology, and Applied Environmental Microbiology (Fig. 10). The different zones, as indicated by Bradford's law, include zone one or the "core zone" with four journals (7.01%), zone two with ten journals (17.54%), and zone three with 40 journals (70.17%) (Fig. 11). Thirty-three percent of the retrieved documents belonged to seven percent of the total journals that constituted the 'core journals' of BBD research. Diseases of aquatic organisms topped the core journals contributing 23 documents. The journal with the highest h index is "Ecology" with a value of 16, followed by Diseases of aquatic organisms and Environmental Microbiology with an h index of 15 (Fig.12). Three clusters are observed in the source co-citation network, with cluster one having eight sources, cluster two with 19 sources, and three with three sources. Even though the second cluster is the largest in terms of the member strength, the thicker lines denote that the first cluster is the stronger one indicating that the eight sources (including Science, Nature, Coral Reefs, Hydrobiologia, *etc.*) coming under this cluster is most frequently cited together (Fig.13).

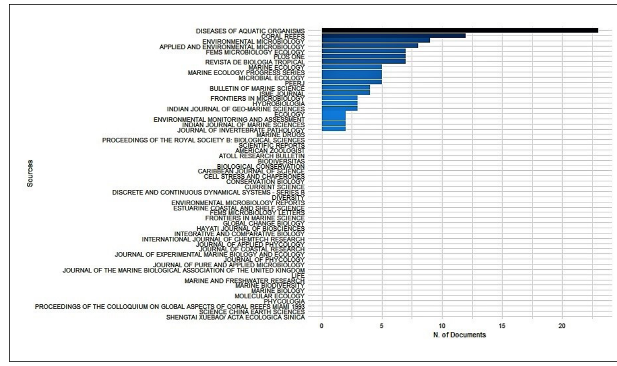

Fig. 10. Most relevant source

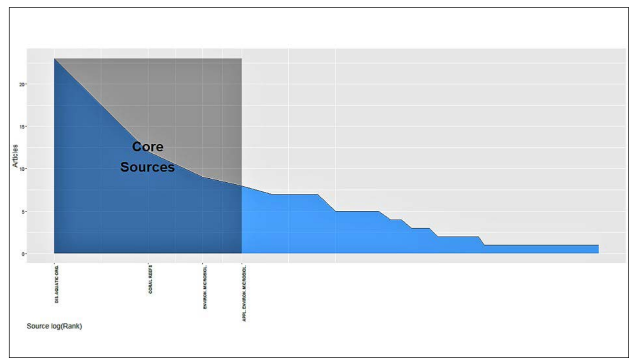

Fig.11. Bradford's law- Core Journals

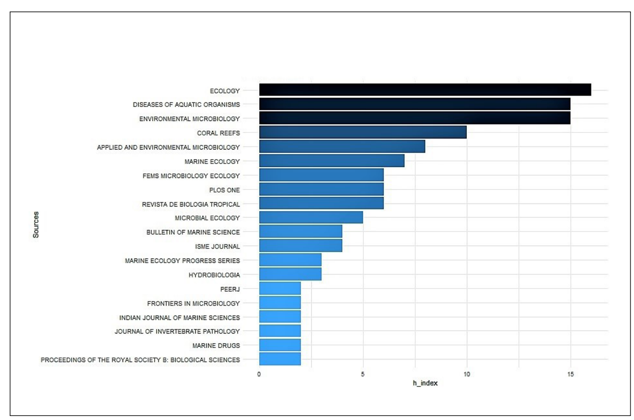

Fig.12. Source impact- H index of Journals

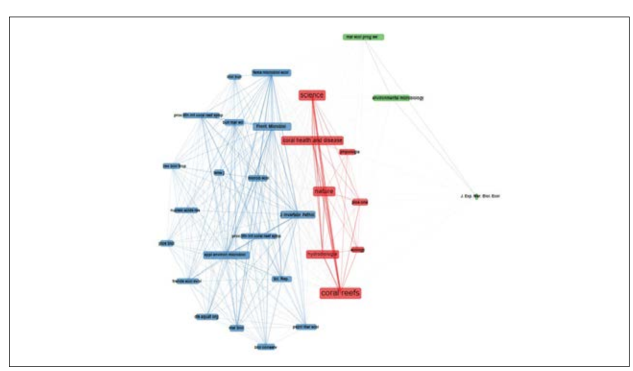

Fig.13. Co-citation Network of Sources

Productivity of Institutes

The Florida International University of USA was the most relevant institute with a contribution of forty articles, followed by James Cook University of Australia (Fig.14). When institute collaboration is analyzed, amongst a total of seven clusters, clusters 1 and 2 were the most noticeable, with nine groups each. In cluster 1, James Cook University and the Australian Institute of Marine Science are more highlighted. The Florida International University, which showed the highest prominence, belonged to the second cluster (Fig. 15).

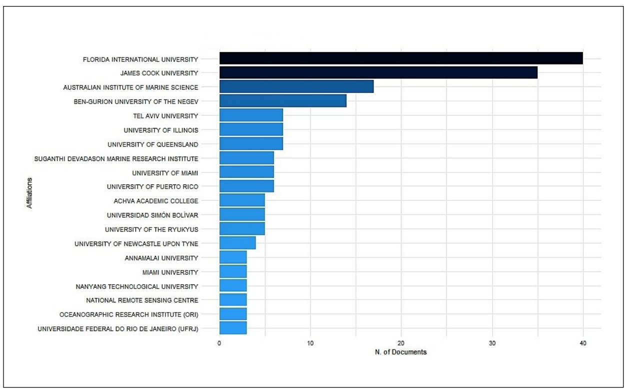

Fig. 14. Most Relevant Affiliations

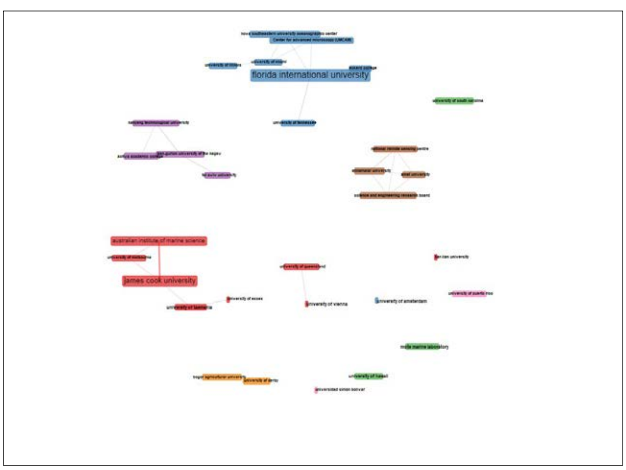

Fig. 15. Collaboration of Institutes

Keyword Analysis and Thematic Map

The analysis of co-occurrence of keywords provided two different clusters- cluster 1(having words like animals, cyanobacterium, microbiology) and Cluster 2 (having words like DNA, phylogeny, genetics and 16 s)- with each cluster comprising of keywords that frequently occur together in articles (Fig.16). Thematic map with four sets namely Anthozoa, animals, disease prevalence, and the microbial community, was also obtained as given in (Fig.17). Different keywords are grouped into clusters, and these clusters are considered as central themes in BBD research.

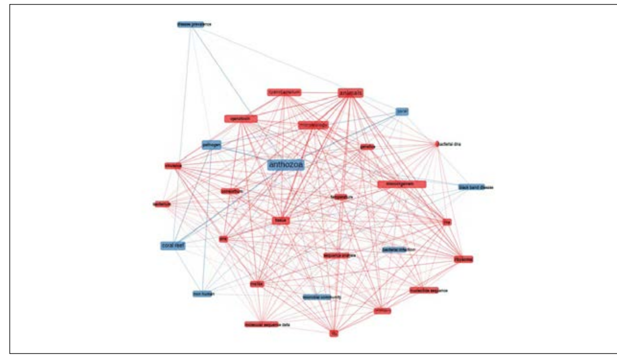

Fig.16. Co-Occurrence Network of Keywords

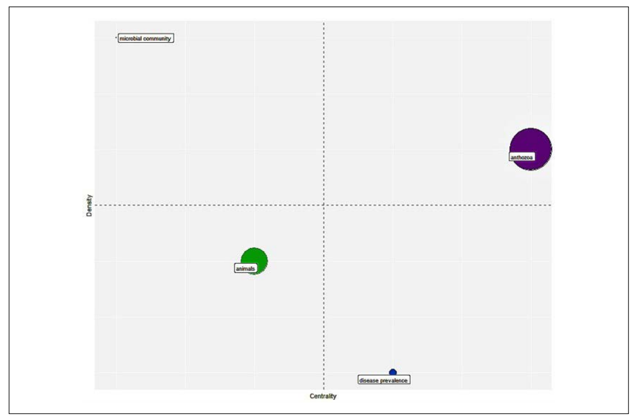

Fig. 17. Thematic Map

Historic direct citation network and Citation analysis

The most relevant citations were mapped in a chronological order to obtain a plot consisting of the most productive 20 articles. The direction of arrows in the historic direct citation network (Fig. 18) represents the history of the past research trends with the significant papers indicated by darkly colored circular nodes such as in the node Friaz-Lopez 2002, Friaz-Lopez 2003. We can visualize that the major research papers occurred between the years 1995-2010. The article Frias-Lopez (2002) was the most globally cited document (Fig. 19), whereas Cooney *et al.* (2002) was the most locally cited document (Fig. 20). The co-citation network of research papers was also examined that revealed the occurrence of two clusters. The first cluster included 14 research papers, among which Sutherland (2004) was the most prominent node (Fig.21). The second cluster had 16 papers, among which Lopez (2002) was the most prominent node interlinked to other papers in the cluster.

Reference analysis: Reference Publication Year (RPY) Spectroscopy

A total of 6486 entries were present in the table of cited

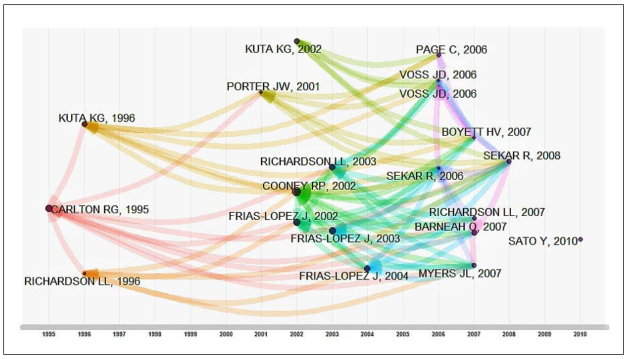

Fig.18. Historical Direct Citation Network

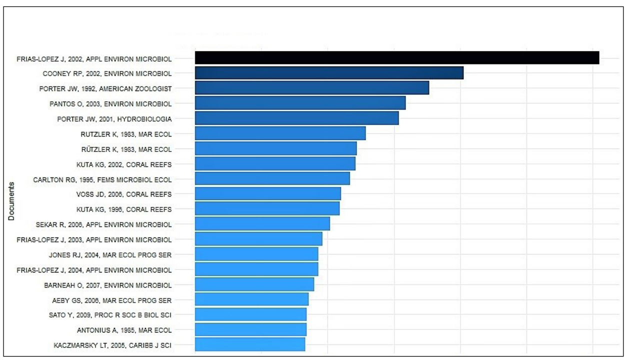

Fig.19. Most Global cited Document

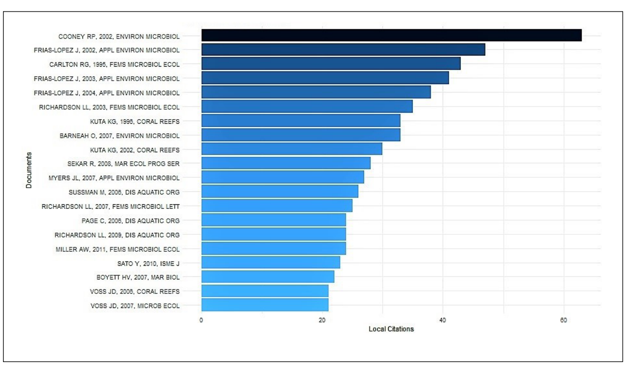

Fig. 20. Most local Cited Document

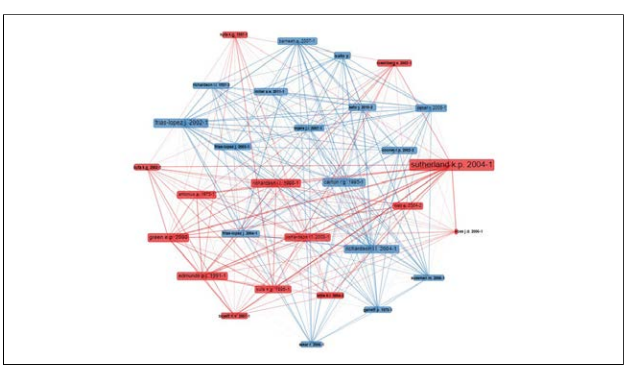
Fig. 21. Cocitation Network of Papers

references. The graph indicates that peaks occurred between 1983-2015. The four most prominent peaks appear during the first decade of the 21st century corresponding to 2002, 2004, 2006, and 2009 (Fig. 22). Among the cited references of the 157 documents, articles of the year 2002 have the highest citation frequency (514). The most local cited reference was "Extent and Effect of Black Band Disease on a Caribbean Reef (1991)" followed by "Abundance and Distribution of Black Band Disease on Coral Reefs in the Northern Florida Keys (1996)" authored by Kuta and Richardson.

Assessment of published literature on BBD has shown that the annual scientific literature production is reasonably good enough as considered in the initial years. This increase can be considered as a reflection of the general global interest invoked by the realization of the radical repercussions of coral diseases on the much fragile and conserved coral reef ecosystem. A sudden decrease in the number of particles observed in some of the years such as 2007, 2008, 2010 and 2012 in the period of study might be due to an increase in the focus on other topics like the bleaching events or other emerging coral diseases which may have grabbed the attention of coral scientists. The majority of the articles (94.9%) were multi-authored articles showing a high level of cooperation between the researchers. The coauthors per document and collaboration index indicate communication and exchange of ideas in the BBD research field is high that may foster scientific advancement in this field.

It is not a matter of surprise that the USA being one of the most developed in research and development spending, has contributed to the top scientific production in BBD research, the etiology and spread of which has impacted their reef ecosystems. The coral reefs of the USA have suffered massive damages from coral diseases (Williams *et al*., 2010; Vargas-Ángel, 2009; Aeby *et al*., 2008). Black Band disease was studied in the Florida and Hawaii reefs (Kuta and Richardson, 1996: Aeby *et al*., 2015). The need to check the extent and effects of black band disease was demanding for the Great barrier reef in Australia, which has witnessed the BBD epizootic (Sato *et al*., 2009), probably conferring it the second position in the ranking of research

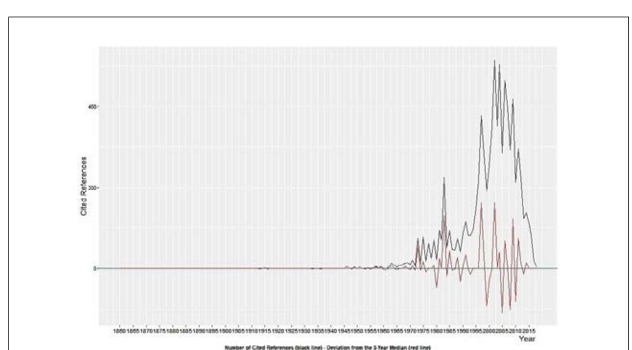

Fig.22. Reference Publication Year Spectroscopy

publications in BBD. Other countries like India, Israel, UK and Indonesia are home to major coral reef ecosystems of the world with BBD afflictions (Haapkylä *et al.*, 2007; Barneah *et al.*, 2007; Haapkylä *et al.*, 2009; Thinesh *et al.*, 2014). The fact that the USA, UK, and Australia are the founding members of the International Coral reef initiative (ICRI) and the other countries that topped the list like India and Indonesia are constituting members complements the findings of the present study. On the contrary, the low scientific production of the Philippines, despite being one of the largest reef nations and a founding member of ICRI, is remarkable. The contributions of Israel are also notable and this may be due to the apparent development of research attitude in Israel. Among the top five most productive countries, India is the only country that lacks collaboration with other nations in BBD research. This goes in hand with the findings of mapping the international scientific collaboration among countries of the world in which India possesses a lower rate of collaboration (Gazni *et al.,* 2012). This may be because in India, studies related to coral diseases are still in their infancy. Although publications from India report the presence of BBD in their respective study areas (Thinesh *et al.,* 2011), works which focus on etiology or microbial communities associated with the disease are sparse. The lack of interest from China despite being a developed nation with diverse coral reef species is also notable. Our findings suggest a lack of research contribution by Commonwealth countries (except Australia, Dominica, UK, and Singapore, South Africa) that account for nearly half of the coral reefs, with over 200 million people depending on these reefs for food and income.

As with the case of the most productive country, the most cited countries were also the USA and Australia. But the third most productive country, Israel, is preceded by the Fifth most productive country when it comes to the land that received the most citations. Moreover, Saudi Arabia, which was lower in scientific production, received a considerable number of citations. This may be due to the relative relevance of the different studies that the Saudi Arabian researchers undertake. Research collaboration is a defining characteristic of the 'Big Science' (Price, 1963) and has been considered a consequence of 'Professionalization of Science' (Beaver & Rosen, 1978). Our results indicate that BBD research requires more focus and fostering in many developing countries requiring further active research collaborations with the developing countries. The prominent collaboration in global BBD research is a trio among the USA, UK, and Australia, which is highly remarkable. Among the most productive countries, the collaboration between the USA and Australia is high. The USA is collaborating with more countries than Australia and the UK.

The observation that the most productive author is Richardson L. L. can be connected to her affiliation with the most relevant institute, Florida International University both of which supplements the scientific productivity of the USA. A similar pattern is observed with the second most productive author Willis B. and her institute, James Cook University. Richardson has the most significant number of articles published and shows high collaboration with other authors. The collaboration network of authors most probably implies that clusters are formed by authors who are affiliated with the same institutes. This may be due to the possibility and easiness of these authors to cooperate with works of each other due to their apparent proximity and common area of interest. Assessment of author productivity by Lotka's law summarizes that a major part of the scientific literature emanated from a smaller group of researchers. The authors belonging to these smaller groups have many articles to their credit, and their counterparts have made only minor contributions. This is reflected in the fact that a high percentage (70%) of authors have only single contributions. When interpreted in another way, it may be observed that researchers who are highly focused and dedicated to BBD research are only a minority.

The critical works concerning the BBD were highly concentrated in a small number of core journals. Diseases of Aquatic Organisms is a journal dealing with diseases of marine, benthic, and brackish lifeforms, which may be why it became the most relevant source. The cause of the relevance of other core journals like 'Coral Reef', 'Environmental Microbiology' and 'Applied Environmental Microbiology' may be that the topics that were frequently focused like disease causation, prevalence, etiology, microbial communities associated with a disease, *etc.* fitted into the themes covered by these journals so that there was a high probability of authors choosing these journals for publication.

The current study analyses the pattern of co-citation of documents, authors, and sources. The bibliographic data can be related to each other by co-citation networks based on co-citation strength. Analyzing the extent of joint citation of authors or papers which have significant contributions to a particular research domain is one way to represent the relationship between key concepts in it (Chen *et al.,* 2007). The co-citation networks of papers obtained in the current study present two clusters. Detailed analysis of the papers in each set reveals that the first cluster is formed by articles that examine the abundance, distribution, ecological and environmental relations of the disease. In contrast, the second cluster is dominated by articles that probe the microbial communities, microbial genetics, and molecular level examination of bacteria associated with the disease. Co-citation networks of sources reveal that popular journals like Nature, Science, Ecology and the Coral Reefs form a cluster, implying these are frequently cited together which may be due to the implicit superior standard or specialization of these journals when compared to the other cluster that includes journals mainly devoted to microbiology, marine biology, and environmental microbiology.

The article Frias-Lopez (2002) observed as the most globally cited document was the first work to carry out culture-independent 16s rRNA phylogenetic analyses of microbial communities that inhabited seawater, healthy, BBD-infected and dead coral surface, the result of which suggested that all these microbial communities showed marked distinctiveness that amused the scientific community. Cooney authored the paper "Characterization of the bacterial consortium associated with black band disease in coral using the molecular microbiological technique", the most locally cited document. This was also a celebrated paper as this provided a comprehensive characterization of BBD microbial community via molecular screening technique that gave many fruitful insights such as identification of α-proteobacterium, a hitherto unrecognized potential pathogen of BBD, which was already known to cause the Juvenile Oyster disease.

Reference Publication Year spectroscopy analyses the references that enable us to detect the historical papers that were more frequently cited within the field of black band disease research. It analyses the year and the number of citations corresponding to each year. Among the cited references of the 157 documents, articles of the year 2002 have the highest citation frequency (514). The most local cited reference was "Extent and Effect of Black Band Disease on a Caribbean Reef (1991). Careful analysis of the cited references is essential to understand their real significance (Marx *et al.,* 2014). Analysis of the historiography outlines the milestone articles that can be considered as the 'turning points' in BBD research. This includes the articles authored by Carlton in 1995, Richardson in 1996, Kuta in 1996, Porter in 2001, and the list concluding with Sato in 2011. The historic direct citation network is consistent with the most cited documents that suggest the impact rippled by these articles throughout the timespan of BBD research.

The co-occurrence network of words delineates the cluster of words that occur frequently and it is observed that the words that co-occur are cyanobacteria, phylogeny, sequence analysis, ribosomal, nucleotide sequence, *etc.* A probable reason may be that these words show a high correlation as they are related to the molecular level and genome studies and tend to occur in connection with each other in BBD research. When traced back, it appears that the initial investigations about BBD are concentrated on the etiological agent (Rützler and Santavy, 1983) as well as the characteristic manifestations of the disease (Richardson, 1998). The search for the pathological causative became worthy when studies relinquished the notion of a single etiological agent and ultimately welcomed the hitherto novel concept of microbial consortium causing the coral diseases (Richardson and Carlton, 1993; Richardson, 1997, Richardson *et al.,* 2007; Richardson, 2004). This can be considered as a milestone in coral disease research as consequently prodigious work amassed on the identification of members of this microbial consortium (Cooney *et al.*, 2002; Frias-Lopez *et al.,* 2003; Frias-Lopez *et al.,* 2004; Viehman *et al.*, 2006; Sekaer *et al.*, 2006; Barneah *et al.,* 2007; Sekar *et al.,* 2008; Rasoulouniriana *et al.*, 2009; Miller and Richardson, 2011). Subsequent studies also followed the identification of microbial toxin microcystin. Abundance, spatial dynamics, and prevalence of BBD were widely studied. Molecular studies like genetic analyses of pathogenic bacterial communities were also prevalent. The results regarding the thematic map obtained in the present bibliometric analysis need to be related to the aforementioned route of black band research. The thematic map can also be discussed in terms of the relative importance gained by the topics that include the basic themes like "disease prevalence" in the lower right quadrant and the specialized theme "microbial community" in the upper left quadrant.

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References

Aeby, G., T. M. Work, D. Fenner and E. Didonato. 2008. Coral and crustose coralline algae disease on the reefs of American Samoa. Proceedings of the 11th International Coral Reef Symposium, Fort Lauderdale, p. 7-11.

Aeby, G.S., T. M. Work, C. M. Runyon, A. Shore-Maggio, B. Ushijima, P. Videau, S. Beurmann and S. M. Callahan. 2015. First record of black band disease in the Hawaiian archipelago: response, outbreak status, virulence, and a method of treatment. *PLoS ONE*, 10(3): e0120853.

Antonius, A. 1973. Tenth meeting of the Association of Island Marine Laboratories of the Caribbean. Mayaguez, Puerto Rico: University of Puerto Rico, 3pp.

Antonius, A. 1985. Coral diseases in the Indo-Pacific: A first record. *Mar. Ecol.,* 6(3):197-218.

Antonius, A. 1988. Black band disease behavior on Red Sea reef corals. Proceedings 6th International Coral Reef Symposium, Australia, 3:145-150.

Aria, M. and C. Cuccurullo. 2017. bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Informetr.,* 11(4): 959-975.

Barneah, O., E. Ben-Dov, E. Kramarsky-Winter and A. Kushmaro, 2007. Characterization of black band disease in Red Sea stony corals. *Environ. Microbiol.*, 9(8):1995-2006.

Beaver, D. and R. Rosen. 1978. Studies in scientific collaboration: Part I. The professional origins of scientific co-authorship. *Scientometrics*, 1(1): 65-84.

Bruckner, A. 2009. The global perspective of incidence and prevalence of coral diseases. Coral Health and Disease in the Pacific: Vision for Action, 90 pp.

Carpenter, K. E., M. Abrar, G. Aeby, R. B. Aronson, S. Banks, A. Bruckner and G. J Edgar. 2008. One-third of reef-building corals face elevated extinction risk from climate change and local impacts. *Science*, 321(5888): 560-563.

Chen, C., I. Y. Song and W. Zhu. 2007. Trends in conceptual modeling: Citation analysis of the ER conference papers (1979-2005). Proceedings of the 11th International Conference on the International Society for Scientometrics and Informatrics, p.189-200.

Chiu, W. T., J. S. Huang and Y. S. Ho. 2004. Bibliometric analysis of severe acute respiratory syndrome-related research in the beginning stage. *Scientometrics*, 61(1): 69-77.

Cooney, R. P., O. Pantos, M. D. L Tissier, M. R. Barer, A. G O´ Donnell and J. C. Bythell. 2002. Characterization of the bacterial consortium associated with black band disease in coral using molecular microbiological techniques. *Environ. Microbiol.,* 4(7): 401-413.

Delwiche, F. A. 2018. Bibliometric Analysis of Scholarly Publications on the Zika Virus, 1952–2016. *Sci. Technol. Libr.*, 37(2): 113-129.

Dinsdale, E. A. 2002. Abundance of black-band disease on corals from one location on the Great Barrier Reef: a comparison with abundance in the Caribbean region. Proceedings of the Ninth International Coral Reef Symposium, Bali, 2: 1239-1243.

Durieux, V. and P. A. Gevenois. 2010. Bibliometric indicators: quality measurements of scientific publication. *Radiology*, 255(2): 342-351.

Edmunds, P. J. 1991. Extent and effect of black band disease on a Caribbean reef. *Coral Reefs*, 10(3): 161-165.

Ellegaard, O. and J. A. Wallin. 2015. The bibliometric analysis of scholarly production: How great is the impact? *Scientometrics*, 105(3): 1809-1831.

Frias-Lopez, J., G. T. Bonheyo, Q. Jin and B. W. Fouke. 2003. Cyanobacteria associated with coral black band disease in Caribbean and Indo-Pacific reefs. *Appl. Environ. Microbiol.*, 69(4): 2409-2413.

Frias-Lopez, J., J. S. Klaus, G. T. Bonheyo and B. W. Fouke. 2004. Bacterial community associated with black band disease in corals. *Appl. Environ. Microbiol.*, 70(10): 5955-5962.

Garrett, P. and H. W. Ducklow. 1975. Coral diseases in Bermuda. *Nature*, 253(5490): 349.

Gazni, A., C. R. Sugimoto and F. Didegah. 2012. Mapping world scientific collaboration: Authors, institutions, and countries. *J. Am. Soc. Inf. Sci. Technol.,* 63(2): 323-335.

Green, E. P. and A. W. Bruckner. 2000. The significance of coral disease epizootiology for coral reef conservation. *Biol. Conserv.*, 96(3): 347-361.

Haapkylä, J., A. S. Seymour, J. Trebilco and D. Smith. 2007. Coral disease prevalence and coral health in the Wakatobi Marine Park, south-east Sulawesi, Indonesia. *J. Mar. Biol. Assoc. UK,* 87(2): 403-414.

Haapkylä, J., R. K. Unsworth, A. S. Seymour, J. Melbourne-Thomas, M. Flavell, B. L. Willis and D. J. Smith. 2009. Spatio-temporal coral disease dynamics in the Wakatobi Marine National Park, south-east Sulawesi, Indonesia. *Dis. Aquat. Org.,* 87(1-2):105-115.

Kaczmarsky, L. T. 2006. Coral disease dynamics in the central Philippines. *Dis. Aquat. Org.*, 69(1): 9-21.

Kuta, K. G. and L. L. Richardson. 1996. Abundance and distribution of black band disease on coral reefs in the northern Florida Keys. *Coral reefs*, 15(4): 219-223.

Marx, W., L. Bornmann, A. Barth and L. Leydesdorff. 2014. Detecting the historical roots of research fields by reference publication year spectroscopy (RPYS). *J. Assoc. Inf. Sci. Technol.*, 65(4): 751-764.

Miller, A.W. and L. L. Richardson. 2011. A meta-analysis of 16S rRNA gene clone libraries from the polymicrobial black band disease of corals. *FEMS Microbiol. Ecol.*, 75(2): 231-241.

Montano, S., G. Strona, Seveso, D., D. Maggioni and P. Galli. 2016. Widespread occurrence of coral diseases in the central Maldives. *Mar. Freshw. Res.*, 67(8):1253-1262.

Montilla, L. M., A. Ascanio, A. Verde and A. Croquer. 2019. Systematic review and meta-analysis of 50 years of coral disease research visualized through the scope of network theory. *Peer J.,* 7: e7041.

Narotsky, D., P. H. Green and B. Lebwohl. 2012. Temporal and geographic trends in celiac disease publications: a bibliometric analysis. *Eur. J. Gastroenterol. Hepatol.*, 24(9): 1071-1077.

Page, C. and B. Willis. 2006. Distribution, host range and large-scale spatial variability in black band disease prevalence on the Great Barrier Reef, Australia. *Dis. Aquat. Org.*, 69(1): 41-51.

Price, D. J. D. S. 1963. *Little science, big science*. Columbia University Press, New York, 119 pp.

Pritchard, A. 1969. Statistical bibliography or bibliometrics. *J. Doc.,* 25(4): 348-349.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rasoulouniriana, D., N. Siboni, E. Ben-Dov, E. Kramarsky-Winter, Y. Loya and A. Kushmaro, 2009. Pseudoscillatoria coralii gen. nov., sp. nov., a cyanobacterium associated with coral black band disease (BBD). *Dis. Aquat. Org.*, 87(1-2): 91-96.

Richardson, L. L. 1997. Occurrence of the black band disease cyanobacterium on healthy corals of the Florida Keys. *Bull. Mar. Sci.,* 61(2): 485-490.

Richardson, L. L. 1998. Coral diseases: what is really known? *Trends Ecol. Evol.*, 13(11): 438-443.

Richardson, L. L. 2004. Black band disease. In Coral health and disease. Springer, Berlin, Heidelberg, 325-336.

Richardson, L. L. and R. G. Carlton. 1993. Behavioral and chemical aspects of black band disease of corals: an *in situ* field and laboratory study.

Richardson, L. L., R. Sekar, J. L. Myers, M. Gantar, J. D. Voss, E. R. Remily, G. L. Boyer, P. V. Zimba and L. Kaczmarsky. 2007. The presence of the cyanobacterial toxin microcystin in black band disease of corals. *FEMS Microbiol. Lett.*, 272(2): 182-187.

Rogers, C. S. and J. Miller. 2013. Coral diseases cause reef decline. *Science*, 340(6140): 1522-1522.

Rützler, K. and D. L. Santavy. 1983. The black band disease of Atlantic reef corals: I. Description of the cyanophyte pathogen. *Mar. Ecol.*, 4(4): 301-319.

Sato, Y., D. G. Bourne and B. L. Willis. 2009. Dynamics of seasonal outbreaks of black band disease in an assemblage of Montipora species at Pelorus Island (Great Barrier Reef, Australia). Proceedings of the Royal Society of London B: *Biol. Sci.*, 276(1668): 2795-2803.

Sekar, R., D. K. Mills, E. R. Remily, J. D. Voss and L. L. Richardson. 2006. Microbial communities in the surface mucopolysaccharide layer and the black band microbial mat of black band-diseased Siderastrea siderea. *Appl. Environ. Microbiol.*, 72(9): 5963-5973.

Sekar, R., L. T. Kaczmarsky and L. L. Richardson. 2008. Microbial community composition of black band disease on the coral host Siderastrea siderea from three regions of the wider Caribbean. *Mar. Ecol. Prog. Ser.*, 362: 85-98.

Sutherland, K. P., J. W. Porter and C. Torres. 2004. Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals. *Mar. Ecol. Prog. Ser.*, 266: 273-302.

Thinesh, T., G. Mathews, K. D. Raj and J. P. Edward. 2014. Variation in black and white band disease progression in corals of the Gulf of Mannar and Palk Bay, Southeastern India. *Dis. Aquat. Org.,* 110(3): 227-234.

Thinesh, T., G. Mathews and J. P. Edward. 2011. Coral disease prevalence in the Palk Bay, Southeastern India--with special emphasis to black band. *Indian J. Geo-Mar. Sci.,* 40(6): 813-820.

Thompson, D. F. and C. K. Walker. 2015. A descriptive and historical review of bibliometrics with applications to medical sciences. *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*, 35(6): 551-559.

Vargas-Ángel, B. 2009. Coral health and disease assessment in the US Pacific Remote Island Areas. *Bull. Mar. Sci.*, 84(2): 211-227.

Viehman, S., D. K. Mills, G. W. Meichel and L. L. Richardson. 2006. Culture and identification of Desulfovibrio spp. from corals infected by black band disease on Dominican and Florida Keys reefs. *Dis. Aquat. Org.*, 69(1): 119-127.

Williams, G. J., G. S. Aeby, R. O. Cowie and S. K. Davy. 2010. Predictive modeling of coral disease distribution within a reef system. *PLoS ONE*, 5(2): e9264.