Overview of Coral Morphology and Plasticity Research Using Bibliometric Methods

Ridha Alamsyah[1,2] *, Neviaty P. Zamani[2], Dietriech G. Bengen[2], I Wayan Nurjaya[2], Derek Soto[3]

[1]Aquatic Resources Management, Faculty of Agriculture, Muhammadiyah Sinjai University
Jl. Teuku Umar No.8 B, Sinjai Utara, Sinjai, Sulawesi Selatan 92615 Indonesia
[2]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, IPB University
Jl. Raya Dramaga Kampus IPB Dramaga Bogor 16680 West Java, Indonesia
[3]Department of Life Science, National Taiwan Normal University, Taiwan
No. 162 號, Section 1, Heping E Rd, Da'an District, Taipei City, Taiwan 106
Email: ridhaalamsyah@apps.ipb.ac.id

Abstract

One of the determining variables that influences coral growth morphology is the aquatic environment. Reef corals are unusual organisms with plant-like development patterns. Reef growth is influenced greatly by the aquatic environment, particularly hydro-oceanography. The same type of coral can have different morphological forms. This mismatch in form can lead to type identification mistakes. There is still a lack of research on morphological changes as an impact of coral plasticity in responding to environmental variables. The goal of this work is to compile a bibliography of coral morphological plasticity studies. Publish or Perish (PoP) program locates the Scopus database and processes the articles. After screening, 101 of the 138 articles found in the Scopus database are eligible to be found. Mendeley reference manager software is then used to handle the selected references. After maintaining the database, use VOSviewer software to classify and visualize the data. The findings suggest that the research topic was chosen based on keywords. Coral morphological plasticity research is primarily focused on the terms coral colonies and species. Small-scale coral morphology, morphological variability, and coral morphometrics are among the topics that have received little attention. The possibility of conducting research on the three subjects is still open. There are still many unanswered mysteries about coral. This work is crucial to research since it illustrates the direction of future plans for exposed coral morphology and plasticity. This review serves as a useful starting point for future coral morphology and plasticity research.

Keywords: *Morphodynamics, variability, adaptability, future, survive*

Introduction

Coral reefs in the waters have an essential role in the survival of various biota, especially in tropical waters such as Indonesia. An excellent coral ecosystem can provide various biological resources of substantial economic value. In addition, it also functions physically as a wave barrier that protects the coastal area and affects the morphodynamics of the beach (Martins *et al*., 2019; Yao *et al*., 2019). The fringing coral reefs, which are abundant, are currently experiencing severe stress. The primary pressure is caused by human activities, due to global warming. There has been a change in global coral cover due to large-scale coral bleaching. Apart from being global, local and regional threats are also unavoidable. The emergence of various coral diseases, the threat of spiny starfish, tropical storms, overfishing or destructive fishing, and worsening water quality (Blackstone and Parrin, 2020; Souter *et al*., 2021). Thus, maximum effort is needed to prevent and anticipate the level of damage to coral reefs, which continues to increase.

The constituent components in an ecosystem greatly determine the ecosystem's success in supporting all aspects of life in it. Each organism has a different function and forms a series of life interconnected with each other. It is essential to know the various types of organisms that make up the composition of the coral reef ecosystem to determine the level of success and resilience of the ecosystem. These organisms carry out their roles well to form a resilient ecosystem resistant to internal and external pressures. The functional structure of an ecosystem is widely regarded as a critical indicator of its resilience status of an ecosystem (Bellwood *et al*., 2018).

As the main constituent components, corals will directly influence the ecosystem if there is a

*) Corresponding author

https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.27.4.349-357
Received : 29-08-2022
Accepted : 27-11-2022

change or disturbance. There are many life challenges in the growing and developing coral organisms (polyps) in reef ecosystems. One of them is environmental disturbance or habitat, which can change at any time. These changes are sometimes caused by natural phenomena such as climate change. However, most of what happens is caused by human activities that tend to be destructive. Coral organisms need mechanisms to respond to the changes that occur. The most significant impact that will be faced is environmental change. Habitat and environmental conditions will be closely related to the abundance and diversity of coral reefs and other organisms in a location (Fatimah *et al.,* 2018*;* Fukunaga *et al*., 2020; Rivera *et al*., 2021).

In the process of adaptation and survival, the morphological structure of the coral structures formed will adapt to the existing environmental conditions. Thus, it will change the morphological structure that has been known so far. The ability to adjust the structure of coral structures in relation to environmental influences is known as the plasticity of reef morphology. This plasticity ability differs from one species to another. Phenotypic plasticity can be broadly defined as the ability of one genotype to produce more than one phenotype when exposed to different environments, as a modification of developmental events by the environment, or as the ability of an individual organism to change its phenotype in response to changing environmental conditions (Kelly *et al*., 2012; Kramer *et al*., 2020).

Research related to the plasticity of coral reefs is still limited. Characteristics and patterns of coral growth are closely related to morphological plasticity. An understanding of this pattern can be used to manage a sustainable coral reef ecosystem. The high level of ecosystem damage due to the influence of various factors is the reason for good management to be immediately carried out based on the characteristics of the existing ecosystem. To understand the extent to which plasticity and environmental influences determine the variation and physical structure of ecosystems engineers are needed to predict how ecosystem structures change. Phenotypic plasticity plays a role in environmental adaptation in determining coral morphology zoning (Brambilla *et al*., 2022). This study provides a bibliometric approach to studies related to the plasticity of corals in adapting to environmental conditions to survive. Identify trends and indicators that determine the plasticity of coral reefs to understand better research progress related to the ability of plasticity and morphology coral.

Materials and Methods

This research uses bibliometric literature review by documenting trends and focus research areas related to coral plasticity morphology. This bibliometric method is carried out more scientifically and objectively than conventional literature reviews (Strozzi *et al*., 2017). The bibliometric literature review is based on a systematic and explicit method (Garza-Reyes, 2015). This research method adopts a five-step method (Setyaningsih *et al.,* 2018; Hudha *et al.,* 2020) as shown in Figure 1.

Determining search keywords

The literature search was conducted in November 2021 using the keyword "Corals Morphology Plasticity". All articles analyzed in this study were taken from the Scopus database. The use of the scopus data base was chosen to obtain the number of studies on the plasticity of coral morphology at this time from reputable sources. Reference search using Publish or Perish Software was chosen because it has proven to be the most effective way to find articles (Andrews, 2021; Baneyx, 2008). The first search entered a query language into the PoP software with the keywords "Corals Morphology Plasticity".

Initial search results

This search was carried out specifically for journals and proceedings without using a sampling period, considering that research related to coral morphology is still very minimal. Search results using Publish or Perish obtained 138 articles.

Figure 1. Five-step method of bibliometric analysis

The results are compiled in a Research Information Systems (RIS) format to include all critical article information, including paper title, author's name and affiliation, abstract, keywords, and references.

Refinement of search results

The articles that match and are indexed in the Scopus database are filtered. This data does not include newspapers, books, book reviews, and book chapters. The results obtained were 101 articles. Only selected journal articles. Then to make appropriate repairs, the file is saved in the form of a RIS file. The RIS data was imported into the statistics bibliography software 351. The resulting RIS file was used for further data analysis.

Compiling initial data statistics

The collected data is stored in the form of RIS. All of the journal article's parts are initially checked (year of publication, volume, number, pages, etc.), and if any data are missing, more information is needed. Data analysis was carried out to classify articles according to the year and source of publication and publisher.

Data analysis

The visualization data consists of the most cited articles, the most researched coral genus, the publisher that publishes the most coral plasticity research results. In addition, the authors and countries have conducted the most research related to coral morphology and plasticity. This analysis uses Power BI. As for the bibliometric analysis in this study using data from the Publish or Perish software (Hudha *et al*., 2020; Babalola and Nwanzu, 2021). However, to analyze and visualize the bibliometric network, using the VOSviewer software (Martínez-López *et al.,* 2020; Shukla *et al.,* 2020). VOSviewer is used because of its ability to work efficiently with large data sets and provide a variety of exciting visuals, analysis and investigations (Cavalcante *et al*., 2021). VOSviewer can also be used to explore data, map, and group articles taken from database sources (Xie *et al*., 2020).

Result and Discussion

There are several studies on the plasticity and morphology of corals, while the research used are from 1979 to 2021. The results of the review analysis use Publish or Perish software to determine the keywords that appear most often. The number of keywords that appear most often is adjusted to the needs of collecting analytical data. The researcher tries to present the most relevant contributions to this research. The step is taken by taking all articles with the keyword "Corals Morphology Plasticity", with the highest citation value (top 10 articles cited). A list of the top 10 articles with the most citations can be seen in Table 1.

The highest citation indexed by Scopus is the article by Grottoli *et al.* (2006). This article discusses heterotrophic plasticity in bleaching corals and it was cited by 523 research articles and published by the Journal of Nature. In general, research on morphological plasticity is still low with a high level of diversity. Characteristics of coral growth and morphology are primarily determined by the environment in which the coral grows and develops. The ability of plasticity in the formation of coral skeletons varies. The type of growth such as branching, crusty, or massive greatly affects plasticity. Information about this is still minimal.

The object of study is related to coral morphology and plasticity research of 28 genera, but the most studied are from the genus Pocillopora, namely 51 articles. Pocillopora is a genus getting a lot of attention, especially related to environmental influences such as hydro-oceanography which is mainly related to the shape and morphological growth of the Pocillopora species. The most studied coral species is *Pocillopora damicornis,* showing various forms in different environments. *Pocillopora damicornis* is often used to explain morphological changes due to environmental influence (Veron, 1995). Branched or submassive corals are widely studied because morphological changes can be seen clearly in a not too long time.

The publishers who contributed the most articles to research related to coral morphological plasticity were also analyzed. In 101 published articles, 90 articles were published from major publishers, namely Springer, followed by Elsevier 49 articles; Wiley Online Library, 32 articles; Royal Society Publishing, 17 articles; and the journal Plos, 15 articles. Other publishers, such as Nature, Int-Res and Frontiersin, have 14 articles, while others have less than ten articles. The countries with the highest number of researchers on coral morphology and plasticity are the USA and Australia. The difference in the number of studies conducted by the USA as many as 107 is very different compared to other countries. This shows the seriousness of the USA in conducting publications related to coral morphological plasticity. In 41 years, there are not too many authors

concerned with studying the morphology of coral plasticity. Arrigoni and Todd with only 7 posts (Arrigoni *et al.,* 2016). This shows that the writing concern regarding this matter is still deficient.

The distribution of researchers on coral morphology and plasticity was highest in the USA with 107 researchers, then Australia with 62 researchers. The distribution is quite scattered, but the highest distribution is in the European region even though the number of articles is low. This geographical distribution shows that the Americas still dominate coral morphology and plasticity research. Overall, this information provides clues about the possibilities and opportunities of conducting research in several countries, including Indonesia.

In this study, bibliometrics to map topics based on titles and keywords is very important. The analysis results are presented in the form of Network Visualization, Overlay Visualization, and Density Visualization. This result is done by measuring the co-occurrence of the title and keywords using "Coral Morphology Plasticity". The use of VOSviewer helps

Table 1. List of publications with total citation the most

No	Publication Year	Author	Title	Cites	Publication
1	2006	Grottoli, AG; Rodrigues, LJ; Palardy, JE	Heterotrophic plasticity and resilience bleached corals	523	nature
2	2008	Todd, PA.	Morphological plasticity in scleractinian corals	257	Biological Reviews
3	1994	Lesser, MP; Weis VM; Patterson, MR; Jokiel, PL.	Effects of morphology and water motion on carbon delivery and productivity in the reef coral, Pocillopora damicornis (Linnaeus): Diffusion barriers, inorganic carbon limitation, and biochemical plasticity	212	Journal of Experimental Marine Biology and Ecology
4	1997	Bruno, JF; Edmunds, PJ.	Clonal variation for phenotypic plasticity in coral *Madracis mirabilis*	144	Ecology
5	2014	Schmidt-Roach, S; Lundgren, P; Miller, KJ; Gerlach, G; Noreen, AME; Anreakis, N	With eyes wide open: A revision of species within and closely related to the Pocillopora damicornis species complex (Scleractinia; Pocilloporidae) using morphology and genetics	135	Zoological Journal of the Linnean Society
6	1979	Foster, AB.	Phenotypic Plasticity in the reef corals *Montastrea annularis* (Ellis and Solander) and *Siderastrea siderea*	135	Journal of Experimental Marine Biology and Ecology
7	2001	Diekmann, OE; Body, RPM; Stam, WT; Olsen, JL.	Molecular genetic evidence for probable reticulate speciation in the coral genus Madracis from a Caribbean fringing reef slope	100	Marine Biology
8	2013	Schmidt-Roach, S; Lundgren, P; Miller, KJ; Gerlach, G; Noreen, AME; Anreakis, N	Assessing hidden species diversity in the coral Pocillopora damicornis from Eastern Australia	98	Coral Reefs
9	2015	Tambutté, E; Venn, AA; Holcomb, M; Segonds, N; Techer, N; Zoccola, D.	Morphological plasticity in the coral skeleton under CO_2-driven seawater acidification	97	Nature Communications
10	2013	Pinzen, JH; Sampayo, E; Cox, E; Chauka, LJ; Chen, LA; Voolstra, CR; Lajeunesse, TC.	Blind to morphology: Genetics identify several widespread ecologically common species and few endemics among Indo-Pacific cauliflower corals (Pocillopora, Scleractinia)	95	Journal of Biogeography

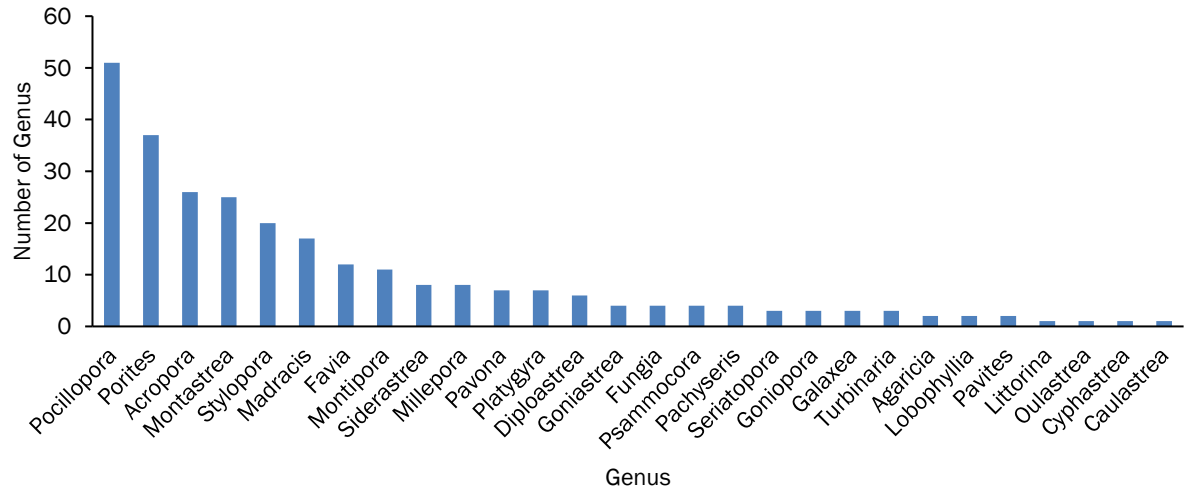

Figure 2. The most studied coral genus

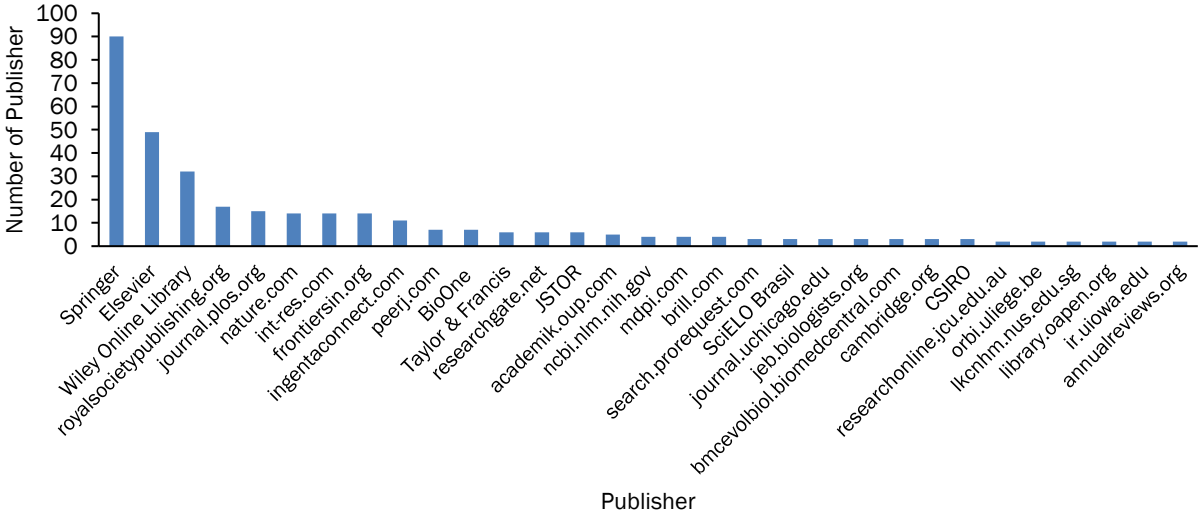

Figure 3. Publishers who publish the most coral plasticity morphology

to find out the relationship of each cluster. Based on the relationships formed, it can be indicated that the development of research on this matter is related.

The network visualization co-occurrence is shown in Figure 6. Based on the analysis obtained, 12 clusters of 310 items. The largest circle is "species", which reveals that the keyword "species" has the most significant number of occurrences in the Scopus database and is included in the first cluster with 73 items. The second cluster with the second-largest font is "coral" 45 items. The third cluster is the largest font in "phenotypic plasticity" and there are 43 items. "Morphology" in cluster 4 and "colony" in cluster 6 also have large circles. Species have links as many as 274, the distance between the species with the turbid and lagoon is very far, indicating that the relationship between them is fragile so that future research opportunities regarding studying species in the turbid and lagoon areas are wide open for research. Cluster 12 only consists of one item: small-scale coral morphology with seven links and two occurrences. Some new words can be linked and investigated in future research. Therefore, more topics can be developed based on these keywords, such as affiliation, city, and country. The above elements can provide a more comprehensive analysis.

Overlay Visualization shows research novelty based on color. The new research looks yellow, including genetic structure, calice level, trophic strategy, stress tolerance, mesophotic depth, and distinct morphotype.

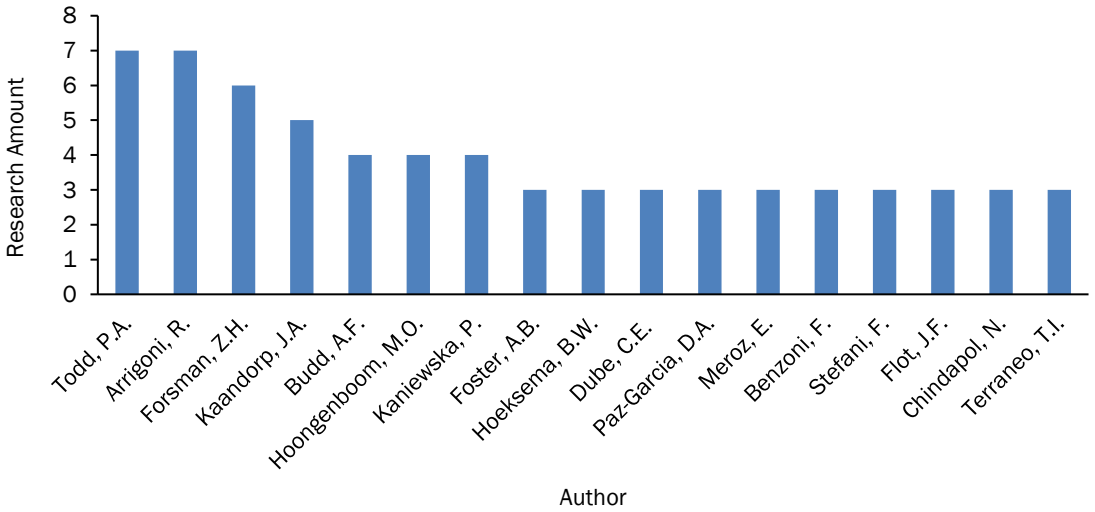

Figure 4. The most published author of coral plasticity morphology

Figure 5. Distribution and amount study about Morphology Coral Plasticity

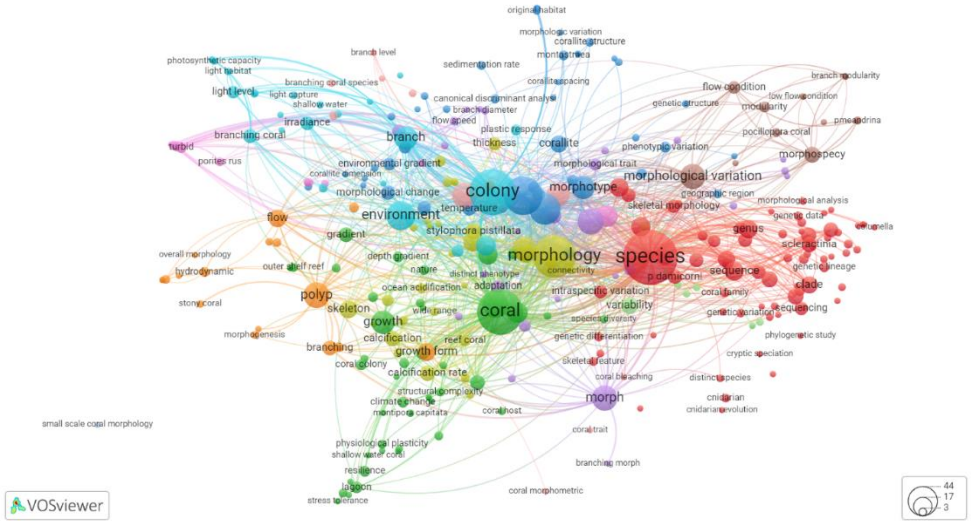

Figure 6. Network visualization

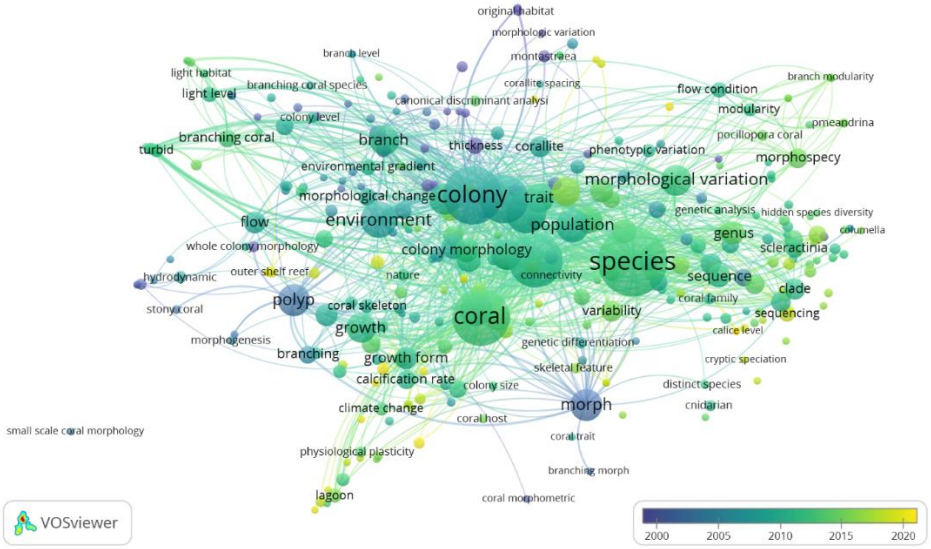

Figure 7. Overlays Visualization

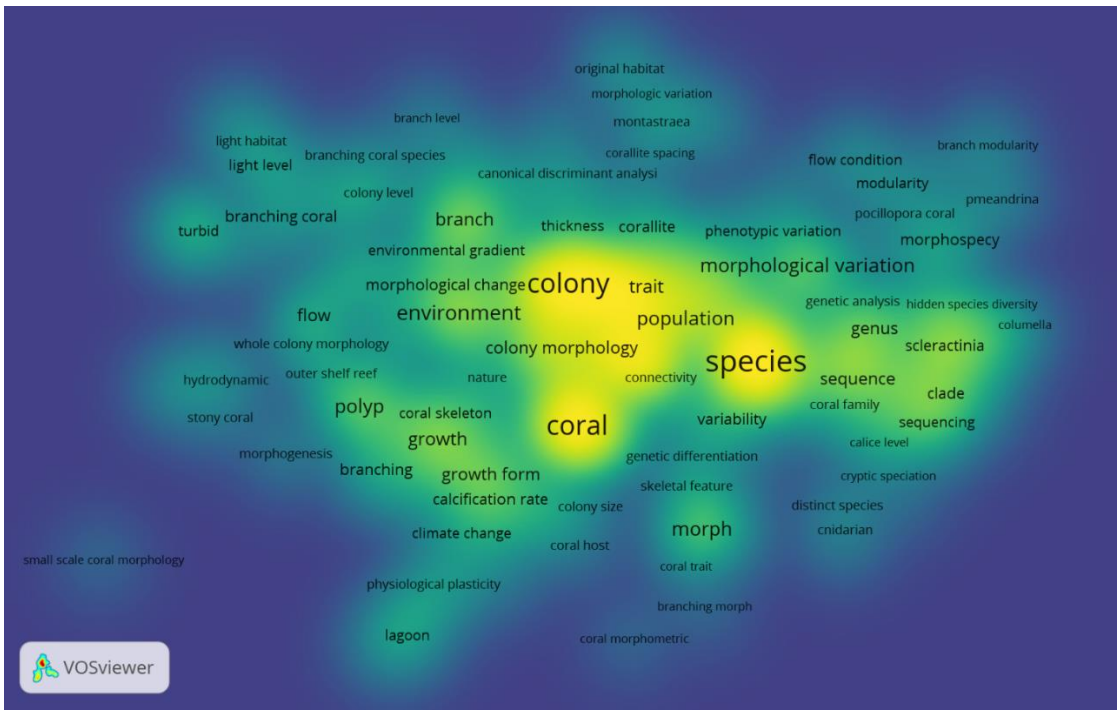

Figure 8. Density Visualization

Many research related to coral colonies and species has been conducted, marked by bright colors on density visualization. Meanwhile, small-scale coral morphology, morphological variation, and coral morphometrics are minimal. This study shows the future plan's direction that coral morphology and plasticity are open and essential to study. Overall, from 1979 to 2021, the number of publications obtained was minimal, so there were opportunities for research to be carried out.

Conclusion

The findings of a review of coral morphology and plasticity studies from 1979 to 2021 are still quite sparse. The topic of coral morphology, morphological variations, and coral morphometrics still has a lot of research potential to be developed further. These topics are useful in order to improve our understanding of hard coral structure. This work demonstrates the future direction of the agenda,

demonstrating that coral morphology and plasticity are both open and significant topics to research.

Acknowledgement

Saying accept love to the Ministry of Education, Culture, Research, and Technology which has helped fund Domestic Education Scholarship. Chancellor of the University of Muhammadiyah Sinjai has given endorsement morale and opportunity for continued education at the Bogor Agriculture Institute.

References

Andrews, R.J. 2021. Publish or Perish? Publish and Perish? Global Neurosurgery in the COVID-19 Pandemic Era. *World Neurosurgery*, 145*:* 45–47. https://doi.org/10.1016/j.wneu.2020.09.018

Arrigoni, R., Benzoni, F., Terraneo, T.I., Caragnano, A., & Berumen, M.L. 2016. Recent origin and semi-permeable species boundaries in the scleractinian coral genus Stylophora from the Red Sea. *Scientific Reports*, 6: 1–13. https://doi.org/10.1038/srep34 612

Babalola, S.S. & Nwanzu, C.L. 2021. The current phase of social sciences research: A thematic overview of the literature. *Cogent Soc. Sci.,* 7(1): 1–20. https://doi.org/10.1080/23311886.2021.1892263

Baneyx, A. 2008. "Publish or Perish" as citation metrics used to analyze scientific output in the humanities: International case studies in economics, geography, social sciences, philosophy, and history. *Arch. Immunol. Ther. Exp.*, 56(6): 363–371. https://doi.org/10.1007/s00005-008-0043-0

Bellwood, D.R., Streit, R.P., Brandl, S.J. & Tebbet, S. B. 2018. The meaning of the term "function" in ecology: A coral reef perspective. *Coral Reef Functional Ecology in The Anthropocene*, 33: 948–961.

Blackstone, N.W. & Parrin, A.P. 2020. Stress, Development, and Evolution in Coral Reef Communities. *Morphogenesis, Environmental Stress and Reverse Evolution*. Springer, Cham. https://doi.org/10.1007/978-3-030-47279-5_11

Brambilla, V., Barbosa, M., Dehnert, I., Madin, J., Maggioni, D., Peddie, C. & Dornelas, M., 2022. Shaping coral traits: plasticity more than filtering. *Mar. Ecol. Prog.*, 692: 53-65. https://doi.org/10.1101/2021.08.19.456946

Cavalcante, W.Q.D.F., Coelho, A. & Bairrada, C.M. 2021. Sustainability and Tourism Marketing : A Bibliometric Analysis of Publications between 1997 and 2020 Using VOSviewer Software. *Sustainability,* 13(9): 4987. https://doi.org/10.3390/su13094987

Fatimah, S., Putra, T.W.L., Kondang, P., Gamelia, L., Syahputra, H., Rizmaaadi, M. & Ambariyanto, A., 2018. Diversity of coral fish at Saebus Island, East Java, Indonesia. In *E3S Web of Conferences*, 31: p. 08021). EDP Sciences.

Fukunaga, A., Burns, J.H.R., Pascoe, K.H., & Kosaki, R.K. 2020. Associations between benthic cover and habitat complexity metrics obtained from 3D reconstruction of coral reefs at different resolutions. *Remote Sensing*, 12(6): p.1011 https://doi.org/10.3390/rs12061011

Garza-Reyes, J.A. 2015. Lean and green-a systematic review of the state of the art literature. *J. Cleaner Production*, 102: 18–29. https://doi.org/10.1016/j.jclepro.2015.04.064

Grottoli, A.G., Rodrigues, L.J., & Palardy, J.E. 2006. Heterotrophic plasticity and resilience in bleached corals. *Nature*, 440(7088): 1186–1189. https://doi.org/10.1038/nature04565

Hudha, M. N., Hamidah, I., Permanasari, A., Abdullah, A. G., Rachman, I. & Matsumoto, T. 2020. Low Carbon Education: A Review and Bibliometric Analysis. *Eur. J. Educ. Res.*, 9(1): 319–329. https://doi.org/10.12973/eu-jer.9.1.319

Kelly, S.A., Panhuis, T.M. & Stoehr, A.M. 2012. Phenotypic plasticity: Molecular mechanisms and adaptive significance. *Compr. Physiol.*, 2(2): 1417–1439. https://doi.org/10.1002/cphy.c110008

Kramer, N., Tamir, R., Eyal, G., & Loya, Y. 2020). Coral Morphology Portrays the Spatial Distribution and Population Size-Structure Along a 5–100 m Depth Gradient. *Front. Mar. Sci.*, 7: 1–13. https://doi.org/10.3389/fmars.2020.00615

Martínez-López, F.J., Merigó, J.M., Gázquez-Abad, J C. & Ruiz-Real, J.L. 2020. Industrial marketing management: Bibliometric overview since its foundation. *Ind. Mark. Manag.*, 84: 19–38. https://doi.org/10.1016/j.indmarman.2019.07.014

Martins, K.A., Pereira, P.S., Esteves, L.S. & Williams, J. 2019. The Role of Coral Reefs in Coastal Protection: Analysis of Beach Morphology. *J.*

Coast. Res., 92: 157–164. https://doi.org/10.2112/SI92-018.1

Rivera, H.E., Aichelman, H.E., Fifer, J.E., Kriefall, N.G., Wuitchik, D.M., Wuitchik, S.J.S. & Davies, S.W. 2021. A framework for understanding gene expression plasticity and its influence on stress tolerance. *Mol. Ecol.*, 30(6): 1381–1397. https://doi.org/10.1111/mec.15820

Setyaningsih, I., Indarti, N. & Jie, F. 2018. Bibliometric analysis of the term "green manufacturing." *Int. J. Manag. Concepts and Philosophy*, 11(3): 315. https://doi.org/10. 1504/ijmcp.2018.093500

Shukla, N., Merigó, J. M., Lammers, T. & Miranda, L. 2020. Half a century of computer methods and programs in biomedicine: A bibliometric analysis from 1970 to 2017. *Comput. Methods Programs Biomed.*, 183: p,105075. https://doi.org/10.1016/j.cmpb.2019.105075

Souter, D., Planes, S., Wicquart, J., Logan, M., Obura, D. & Staub, F. 2021. Status of Coral Reefs of the World: 2020. *Global Coral Reef Monitoring Network*.

Strozzi, F., Colicchia, C., Creazza, A. & Noè, C. 2017. Literature review on the 'smart factory' concept using bibliometric tools. *Int. J. Prod. Res.,* 55(22): 1–20. https://doi.org/10.1080/00207543.2017.1326643

Todd, P.A., 2008. Morphological plasticity in scleractinian corals. *Biol. Rev.,* 83(3): 315-337.

Veron, J.E.N. 1995. Corals In Space and Time : The Biogeography and Evolution of The Scleractinia. Cornell University Press.

Xie, L., Chen, Z., Wang, H., Zheng, C. & Jiang, J. 2020. Bibliometric and Visualized Analysis of Scientific Publications on Atlantoaxial Spine Surgery Based on Web of Science and VOSviewer. *World Neurosurgery*, 137: 1–8. https://doi.org/10.1016/j.wneu.2020.01.171

Yao, Y., Zhang, Q., Chen, S. & Tang, Z. 2019. Effects of reef morphology variations on wave processes over fringing reefs. *Applied Ocean Res.*, 82 (2618): 52–62. https://doi.org/10.1016/j.apor.2018.10.021