Chapter in Book

MEDUSA-LINK MAPS: Early Jellyfish Bloom Prediction for the Sustainability of Fisheries, Coastal Activities, and Tourism

Aimie Rifhan Hashim[1,*], Sharir Aizat Kamaruddin[2], and Mohd Syuib Umar[2]

[1] Faculty of Applied Sciences, Universiti Teknologi MARA Cawangan Perlis, Kampus Arau, 02600, Arau, Perlis, Malaysia; 2021403326@student.uitm.edu.my; ORCID ID (https://orcid.org/0000-0003-3765-1803)

[2] Faculty of Applied Sciences, Universiti Teknologi MARA Cawangan Perlis, Kampus Arau, 02600, Arau, Perlis, Malaysia; shariraizat@uitm.edu.my; ORCID ID (https://orcid.org/0000-0001-7323-2556)

[3] Centre of Studies for Surveying Science & Geomatics, Fac. of Architecture, Planning & Surveying, Universiti Teknologi MARA, Cawangan Perlis, Arau, Malaysia.; 2021217328@student.uitm.edu.my

* Correspondence: shariraizat@uitm.edu.my; +604 988 2157

Abstract: *Jellyfish blooming has occurred around the globe recently and started approaching the coastal region that actively operates with fishing sectors, seaside activities, and tourism. There was undoubtedly commotion, casualties, and even fatalities brought on by jellyfish blooms. Implicitly, the overlap of jellyfish and human populations has terribly impacted the area's socioeconomics. There have been no methods or devices utilized to predict jellyfish blooms based on environmental cues or to employ digital mapping to manage biological risks in the coastal area and ensure the safety of the nearby marine communities. The integration of the spatial and temporal change in jellyfish distribution and water physicochemical water parameters, mediated by Geographic Information System (GIS) technologies, is the basis of the realization and structure of the MEDUSA-LINK maps. The general public, local marine communities, authorities, policy-makers, and even tourists are the target group to ensure the benefits of the MEDUSA-LINK maps. Following the Sustainable Development Goals (SDG) set forth by the United Nations, SDG 14: "Life below water," SDG 3: Good health and well-being, and SDG 13: Climate action and Industrial Revolution 4.0, Big Data in fulfilling predictive demands and maintenance, MEDUSA-LINK maps were brought out to shine and offer a way out.*

Keywords: Jellyfish Blooming; Water Quality Monitoring; Sustainable Coastal Activities.

1. INTRODUCTION

Jellyfish blooming has occurred around the globe in recent decades and started approaching the coastal region that actively operates with fishing sectors, seaside activities, and tourism. Jellyfish abundance, blooming, or massive aggregation, for sure, brought along commotion, casualties, and even fatalities. Implicitly, the overlapped niches between jellyfish and the human population have disastrously impacted local socioeconomics. Factors of jellyfish aggregations are Eutrophication, overfishing, habitat modification for aquaculture, and climate change (Hashim et al., 2022; Purcell et al., 2012; Purcell et al., 2007; Richardson et al., 2009). In advance, human unconsciously promotes blooming by excessive seafood harvesting, removing jellyfish predators, allowing nutrient run-off from

agriculture, introducing alien species, and poor aquaculture conduct (Hashim et al., 2022; Purcell et al., 2012). Currently, the jellyfish blooming incident piqued interest amongst researchers, environmentalists, and even authorities as their occurrence brought uproar, havoc, and tremendous impact on the region affected. Therefore, several jellyfish monitoring approaches are introduced to curb these issues before they worsen.

Several approaches were taken to address the jellyfish blooming occurrences worldwide efficiently. Kennerley et al. (2021) reported the development of the jellyfish monitoring program throughout the United Kingdom and Ireland by mapping the habitat suitability for jellyfish in North Atlantic. Moreover, the stranding of jellyfish species observed on the shore over seasonal variability was also studied in Southeastern Pacific (Fierro et al., 2021). In northern Queensland, Unmanned Aerial Vehicles (UAVs) was used to monitor box jellyfish distribution, which caused death more than 60 death over the years (Rowley et al., 2020). Despite the strategies mentioned above, little research has been done to determine the species composition, abundance, and interactions of jellyfish with the marine environment. As a result, the knowledge of the harmful consequences of jellyfish on Southeast Asian countries is indefinite (Suriyan et al., 2019). Therefore, water quality mapping is proposed as a medium to solve the jellyfish blooming problem in Malaysia.

There is a lack of water quality mapping, particularly in Malaysia. Water quality mapping is crucial to determining the source of contamination and whether it results from anthropogenic or natural sources. For further understanding, the latest water quality mapping is improvised by utilizing spatial and temporal analysis for each water parameter (Hashim et al., 2022; Kamaruddin et al., 2021; Kamaruddin et al., 2022; Kamaruddin et al., 2022). However, water quality mapping related to jellyfish species has never been reported so far using any applications to the best of the author's knowledge. This emphasizes the uniqueness of the suggested innovation approach. Implementing the jellyfish distribution along with the water parameter will alleviate the bottleneck issue in solving the jellyfish blooming problems and provide a predictive method for hindering unwanted jellyfish encounters. By combining those elements, MEDUSA-LINK maps were brought out to shine and provide a way out by giving early jellyfish bloom prediction for the sustainability of fisheries, coastal activities, and tourism consistent with the Sustainable Development Goals established by the United Nations, SDG 14: "Life below water," SDG 3: Good health and well-being, and SDG 13: Climate action and Industrial Revolution 4.0, Big Data in fulfilling predictive demands and maintenance.

2. METHOD & MATERIAL

The MEDUSA-LINK map was made after the current water quality map underwent a thorough revision and improvement using the most recent data, which included the spatiotemporal variation of jellyfish distribution, the spatiotemporal variation of physicochemical and water nutrient parameters, species dominance, and the species diversity index, all mediated by geospatial technology. Visually pleasing digital maps are created using Geographic Information System (GIS) software. By offering preventative measures based on environmental cues, MEDUSA-LINK effectively and efficiently reduces the likelihood that jellyfish accidentally encounter people in busy coastal areas. This software's tools employed spatial statistics for various analyses, including pattern analysis, shape analysis, surface modeling and prediction, spatial regression, statistical comparisons of spatial datasets, statistical modeling and prediction of spatial interaction, and more. Furthermore, MEDUSA-LINK also provided a database of jellyfish native to Malaysian Seas with specific codes and detailed information on jellyfish species based on Field Guide to the Jellyfish of Western Pacific (Centre for Marine and Coastal Studies, 2012).

3. FINDINGS

Authorities, socioeconomic participants in managing coastal tourism, the general public, and local maritime communities, particularly breadwinners in coastal activities, have access to and can use MEDUSA-LINK. MEDUSA-LINK also provides information regarding the spatiotemporal aggregation of jellyfish to forecast the presence and bloom in the coastal area based on environmental cues. MEDUSA-LINK is essential in assisting authorities in upholding the legislation or policy pertaining to managing coastal tourism. MEDUSA-LINK is also essential in formulating a strategy to equip local leaders better to deal with jellyfish seasons or blooms. MEDUSA-LINK must prepare preventative measures, including posting signs warning locals and visitors to stay out of the water during jellyfish blooming seasons. MEDUSA-LINK can currently only be accessible on paper. However, countless MEDUSA-LINK is presently being created digitally. When taken into consideration, MEDUSA-LINK can identify a jellyfish hotspot attack and help prevent accidents that could cause an uproar, casualties, or even fatalities due to unintentional jellyfish contacts.

3.1 Product Objectives

With the use of geospatial software, the spatiotemporal distribution of jellyfish, and the physicochemical characteristics of water, MEDUSA-LINK has been designed to address the problem statement. MEDUSA-ultimate LINK's goals are:

a) To serve as tools or devices to provide predictive information of jellyfish bloom based on environmental cues or water quality parameters.

b) To utilize digitized mapping in managing biological hazards in coastal tourism management and secure the safety of the local marine communities.

3.2 Product Idea

The integration of the spatial and temporal change in jellyfish distribution and water physicochemical water parameters, mediated by Geographic Information System (GIS) technologies, is the basis of the realization and structure of the MEDUSA-LINK maps. A MEDUSA-LINK product explains how jellyfish are distributed over space and time in response to environmental cues and the water quality along the shore of Pulau Langkawi. MEDUSA-LINK offers a large selection of print and digital maps at affordable prices. Our team is the only research and environmental organization that produces up-to-date water quality maps on the distribution of jellyfish species in Malaysia. Local governments, coastal tourist management, socioeconomic stakeholders, and local maritime communities all have different consumer wants that MEDUSA-LINK meets.

3.3 Product Diagram

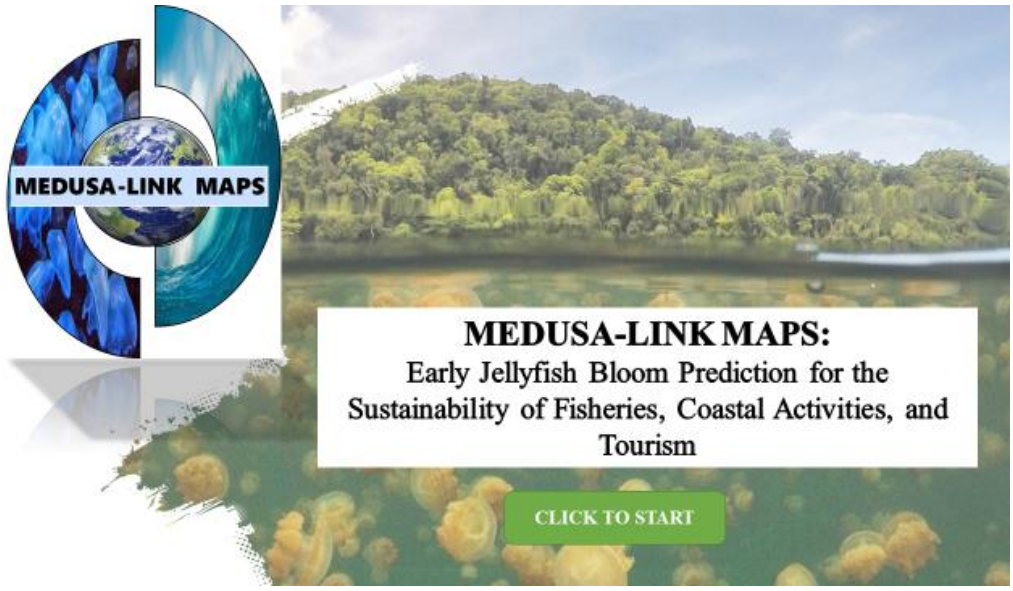

Figure 1. MEDUSA-LINK Maps Logo and Front Page.

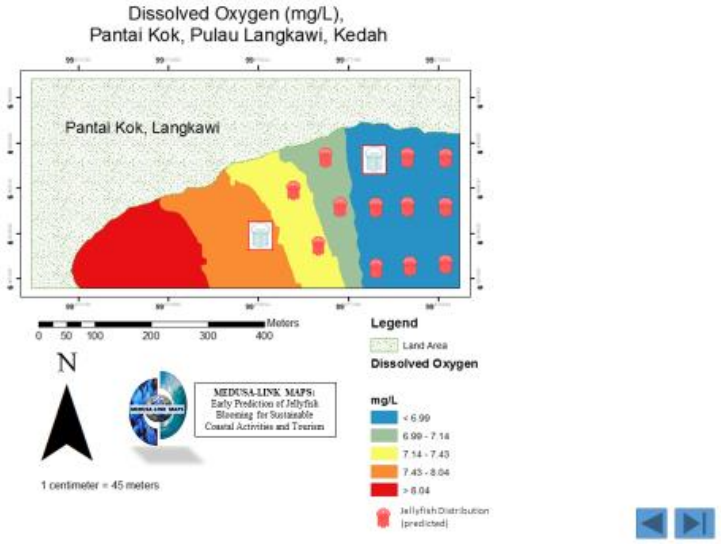

Figure 2. MEDUSA-LINK Maps For Dissolved Oxygen (mg/L) and Jellyfish Distribution of Pantai Kok, Pulau Langkawi, Kedah

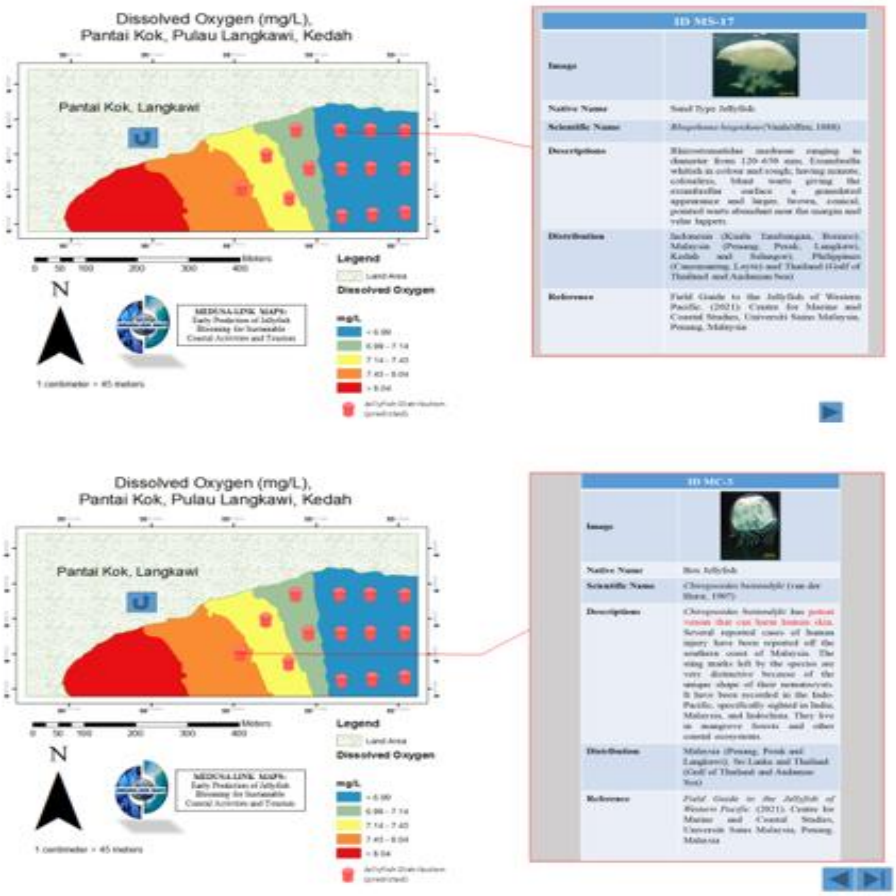

Figure 3. Pop-Up Screen (After Clicking Button) Provide Information About Jellyfish Residing in the Area

4. DISCUSSION

The implementation of MEDUSA-LINK maps in Malaysia can pertain to the sustainability of the fisheries, coastal activities, and tourism, especially in the coastal-dependent region. MEDUSA-LINK maps could hinder or minimize the disastrous impact of jellyfish blooming through early prediction based on environmental cues. Therefore, the effects of jellyfish blooming on coastal fisheries and tourism activities will be appropriately discussed. First, jellyfish blooming could negatively impact the fisheries by reducing the catches, thus lowering the socioeconomic incomes of coastal-dependent areas (Condon et al., 2013). Due to a rise in the number, jellyfish could directly affect fish larvae through predation and indirectly affect fish larvae by feeding on zooplankton and ichthyoplankton, thus, acting as both predators and potential competitors of fish (Purcell et al., 2007). For instance, the social-ecological model was developed to account for the consequences of variations in *Pelagia noctiluca* abundance on local fisheries. The outcomes of the various scenarios demonstrate that *P. noctiluca* has a minimal effect on Catalonia's small pelagic fisheries (Tomlinson et al., 2018). In short, jellyfish blooming could severely impact fisheries by reducing the fish larvae through predation and competition.

Furthermore, jellyfish blooming also could reduce socioeconomic through disrupting coastal activities and tourism. Coastal activities and tourism are entirely dependent on each other. An unwanted encounter with harmful jellyfish could present commotion, casualties, and even fatalities (Centre for Marine and Coastal Studies, 2019). Based on the fact cases in Pulau Langkawi, Kedah, since the bulk of seawater activity happens during the day, the peak time for jellyfish stings was between

12:00 and 6:59 pm. Activities including swimming, entering, and standing in the water were linked to a higher risk of stings (Mohd Suan et al., 2016; Mubarak et al., 2021). A sixth-grader who was stung by a jellyfish while swimming in Teluk Bahang fell into a three-day coma. After experiencing agony for more than a week, Ahmad Azfar Hakim, 12, was hospitalized at the Seberang Jaya Hospital on Thursday. He fell into a coma on Friday, grabbing the public's attention (Centre for Marine and Coastal Studies, 2019; The Star, 2017). To summarize, this compilation of jellyfish envenomation cases called out for action: jellyfish monitoring.

Although jellyfish monitoring has been conducted globally, no adequate and efficient strategies have been adequately drafted and carried out, especially in Malaysia, to prevent another horrendous incident from happening again due to jellyfish blooming. Therefore, the MEDUSA-LINK map is a brilliant approach to alleviate the jellyfish blooming problem by combining the information regarding the spatiotemporal variation of jellyfish and environmental cues, such as water quality parameters, mediated by Geographic Information System (GIS), to present ideally digitized maps for early prediction of jellyfish blooming. Hence, only by MEDUSA-LINK maps, early prediction of blooming could save lives, avoid casualties, and reduce commotion in the near future.

5. CONCLUSION

MEDUSA-LINK is consistent with the Sustainable Development Goals established by the United Nations, SDG 14: "Life below water," SDG 3: Good health and well-being, and SDG 13: Climate action and Industrial Revolution 4.0, Big Data in fulfilling predictive demands and maintenance.

Acknowledgments: The authors express their appreciation to MOHE Fundamental Research Grant Scheme (FRGS/1/2021/WAB11/UITM/03/2) for enabling this study to be conducted successfully. The authors also gratefully acknowledge the generous assistance and support from the academic and non-academic staff for their contribution to this research and publication, especially to UiTM Marine Research Station (MARES); the Research Initiative Group (RIG): Ocean Research, Conservation and Advance (ORCA), and Integrative Natural Product Research; and the Faculty of Applied Sciences, Universiti Teknologi MARA, Perlis Branch, Arau Campus, 02600 Arau, Perlis, Malaysia.

References

Centre for Marine and Coastal Studies. (2019). *Harmful Jellyfish Country Report in Western Pacific* (Issue June).

Centre for Marine and Coastal Studies, U. S. M. (USM). (2012). *Field Guide to the Jellyfish of Western Pacific* (H. M. Aileen Tan Shau Hwai, Sim Yee Kwang (ed.)). https://doi.org/10.1007/978-94-007-2144-9_11

Condon, R. H., Duarte, C. M., Pitt, K. A., Robinson, K. L., Lucas, C. H., Sutherland, K. R., Mianzan, H. W., Bogeberg, M., Purcell, J. E., Decker, M. B., Uye, S. I., Madin, L. P., Brodeur, R. D., Haddock, S. H. D., Malej, A., Parry, G. D., Eriksen, E., Quinõnes, J., Acha, M., … Graham, W. M. (2013). Recurrent jellyfish blooms are a consequence of global oscillations. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(3), 1000–1005. https://doi.org/10.1073/pnas.1210920110

Fierro, P., Arriagada, L., Piñones, A., & Araya, J. F. (2021). New insights into the abundance and seasonal distribution of the Portuguese man-of-war Physalia physalis (Cnidaria: Siphonophorae) in the southeastern Pacific. *Regional Studies in Marine Science*, *41*, 101557. https://doi.org/10.1016/j.rsma.2020.101557

Hashim, A. R., Kamaruddin, S. A., Abd.Aziz, K. N., Tajam, J., Buyong, F., Azis, T. M. F., & Anscelly, A. (2022). Assessment of the Current Spatial-Temporal Variations of pH on the Surface Waters of Kuala Perlis, Perlis. *Journal of Tourism, Hospitality, and Environment Management (JTHEM)*, *7*(28), 52–65. https://doi.org/10.35631/JTHEM.728004.This

Hashim, A. R., Kamaruddin, S. A., Buyong, F., Mat Nazir, E. N., Che Ismail, C.-Z., Tajam, J., Abdullah, A. L., Azis, T. M. F., & Anscelly, A. (2022). Jellyfish Blooming: Are We Responsible? *ICAN INTERNATIONAL VIRTUAL CONFERENCE 2022 (IIVC 2022) PROCEEDINGS – Navigating the VUCA World: Harnessing the Role of Industry Linkages, Community Development and Alumni Network in Academia*, 51–60.

Kamaruddin, S. A., Abd. Aziz, K. N., Roslani, M. A., & Zainol, Z. E. (2021). Sustainable Management of the Coastal Water pH of Pulau Tuba Using the Inverse Distance Weighted (IDW) Method. *Jurnal Intelek*, *16*(2), 162–174. https://doi.org/10.24191/ji.v16i2.428

Kamaruddin, S. A., Abd.Aziz, K. N., Roslani, A., Zainol, Z. E., Ahmad, A., Shaari, M. I., Nazri, R., & Tajam, J. (2022). The Mapping of Salinity Level Using The Inverse Distance Weighted (Idw) Interpolation Method Along The Coastal Area of Pulau Tuba, Langkawi. *Malaysian Journal of Sustainable Environment*, *9*(1), 55. https://doi.org/10.24191/myse.v9i1.17292

Kamaruddin, S. A., Hashim, A. R., Arsyad, M., Mohd Rizal, N. I., Lee, B. K., Ramli, N., Zainal, N. Z., Mohd Tahir, J., Ahmad Afiza, S. A., Hamka, N. Z., & Mat Nazir, E. N. (2022). Assessment of the Spline Interpolation Method'S Performance in Predicting and Mapping the Phosphate Over the Coastal Waters of Pulau Tuba, Langkawi, Kedah. *Journal of Tourism, Hospitality and Environment Management*, *7*(28), 89–101. https://doi.org/10.35631/jthem.728007

Kennerley, A., Lorenzoni, I., Luisetti, T., Wood, L. E., & Taylor, N. G. H. (2021). Mapping habitats for the suitability of jellyfish blooms around the UK and Ireland. *Hydrobiologia*, *848*(7), 1535–1552. https://doi.org/10.1007/s10750-021-04539-4

Mohd Suan, M. A., Tan, W. L., Soelar, S. A., Cheng, H. P., & Osman, M. (2016). Jellyfish stings on Langkawi Island, Malaysia. *Medical Journal of Malaysia*, *71*(4), 161–165.

Mubarak, A. I., Shukri, W. N. A. W. M., & Ismail, A. K. (2021). Estimation of local incidence of jellyfish envenomation in developed marine coastal areas and large populated island on the western coast of Peninsular Malaysia using case surveillance of government health facilities in Manjung, Perak and Langkawi Island. *International Maritime Health*, *72*(2), 93–98. https://doi.org/10.5603/IMH.2021.0017

Purcell, J. E., Uye, S. I., & Lo, W. T. (2007). Anthropogenic causes of jellyfish blooms and their direct consequences for humans: A review. *Marine Ecology Progress Series*, *350*, 153–174. https://doi.org/10.3354/meps07093

Purcell, J., Hermes, M., & Frosr, J. R. (2012). Jellyfish Blooms IV. In *Development in Hydrobiology*. https://doi.org/10.1007/978-94-007-5316-7

Richardson, A., Bakun, A., Hays, G., & Gibbons, M. (2009). *The jellyfish joyride: causes, consequences and management responses to a more gelatinous future.* https://doi.org/10.1016/j.tree.2009.01.010

Rowley, O. C., Courtney, R. L., Browning, S. A., & Seymour, J. E. (2020). Bay watch: Using unmanned aerial vehicles (UAV's) to survey the box jellyfish Chironex fleckeri. *PLoS ONE*, *15*(10 October), 1–17. https://doi.org/10.1371/journal.pone.0241410

Suriyan, S., Haruethaikan, K., & Piyachat, R. E. (2019). A survey of jellyfish sting knowledge among Thai divers in Thailand. *International Maritime Health*, *70*(1), 11–16. https://doi.org/10.5603/IMH.2019.0002

The Star. (2017, March 7). *Jellyfish victim out of coma*. https://doi.org/https://www.thestar.com.my/news/nation/2017/03/07/jellyfish-victim-out-of-coma-boy-unconscious-for-three-days-by-slowacting-toxin-that-shrinks-veins/

Tomlinson, B., Maynou, F., Sabatés, A., Fuentes, V., Canepa, A., & Sastre, S. (2018). Systems approach modelling of the interactive effects of fisheries, jellyfish and tourism in the Catalan coast. *Estuarine, Coastal and Shelf Science*, *201*, 198–207. https://doi.org/10.1016/j.ecss.2015.11.012