Proposal of an Automated Monitoring System of Aquamarine Water Quality in Coral Reef Regions

Gustavo Oliveira Ramos Cruz[1*], João Vitor Fraga dos Santos[1], Gabriel Almeida Vergne de Menezes[1], Juan Nemesio dos Santos[1], Antônio Ivan Messias Soares Júnior[1], Rafael Nascimento de Menezes[1], George Gebers Brizolla[1], Márcio Renê Brandão Soussa[1], Morjane Armstrong Santos de Miranda[1]

[1]SENAI CIMATECUniversity Center; Salvador, Bahia, Brazil

Coral reefs play a crucial role in marine ecosystems, providing habitat and sustenance for diverse marine species. However, they face rapid degradation due to human activities, posing a significant threat to their ecological balance. Monitoring the water quality near these reefs is essential to their preservation, ensuring that critical factors such as temperature, oxygen levels, and salinity remain within appropriate ranges. Traditional monitoring methods are often slow and labor-intensive, requiring field agents to collect data manually. Therefore, there is a pressing need to develop autonomous monitoring devices capable of transmitting real-time data from specific locations to researchers and environmental preservation teams. Doing so can improve our understanding of reef health and respond more effectively to threats.This project aims to contribute to preserving coral reefs by providing timely and accurate data for conservation efforts. By harnessing technology to monitor and protect these vital ecosystems, we can work towards ensuring their long-term survival.

Keywords: Coral Reefs. Monitoring. Automation.

The theoretical foundation of this document resides within the domains of marine conservation and environmental monitoring. Extensive research has underscored the critical importance of coral reefs as ecosystems that provide habitat and sustenance for numerous marine species [1,2].

However, human activities and climate changes have led to the rapid degradation of these systems, posing a significant threat to their ecological balance. According to recent studies [3,4], one of the most effective strategies to preserve these reefs is by continuously monitoring water quality in their vicinity, ensuring that factors such as temperature, oxygen levels, and salinity are maintained at appropriate levels.

Conventional approaches to water quality monitoring typically involve manual data collection, a time-consuming and costly process. It often results in delayed responses to environmental changes and can have long-term adverse effects on the ecosystem. Researchers have recognized the need for automated monitoring systems to collect and analyze real-time data, facilitating swift and effective responses to environmental fluctuations [5].

The efficacy of traditional monitoring approaches for marine ecosystems has been scrutinized in recent literature [6], underscoring the necessity for efficient and precise automated systems. Furthermore, authors have identified key challenges that impede effective monitoring, such as high long-term maintenance costs, inadequate utilization of equipment, and insufficient investment in monitoring initiatives for these environments [7]. To address these challenges, there has been growing interest in leveraging emerging Artificial Intelligence-based technologies, which have the potential to enhance precision, immediacy, and automation in data collection processes.

Indeed, automation offers a promising avenue for real-time monitoring and data collection in marine environments [8]. However, the implementation of such systems remains cost-prohibitive and demands substantial investment. An alternative

Received on 28 January 2024; revised 15 May 2024.
Address for correspondence: Gustavo Oliveira Ramos Cruz. Avenida Orlando Gomes,1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 42701-310. E-mail: gustavo.cruz@ba.estudante.senai.br.

J Bioeng. Tech. Health 2024;7(2):160-163

approach involves the utilization of decentralized biosensors capable of remotely sharing information and providing real-time data about their installation locations [9].

Given the critical state of coral reefs, immediate action is imperative. Human activities and climate change present formidable threats to these ecosystems, underscoring the importance of societal responsibility in their preservation. Monitoring water quality is one of the most effective strategies for safeguarding reefs. While traditional methods are labor-intensive and financially burdensome, automated systems and sensors present viable solutions, albeit requiring significant investment.

Against this backdrop, this study aims to explore recent advancements in automated marine monitoring to develop a solution that automates the assessment of water temperature, oxygen levels, and salinity in coral reef regions. By doing so, this research endeavors to contribute to the preservation of these vital ecosystems.

Materials and Methods

This research adopts a descriptive-qualitative methodology, utilizing articles, journals, and pertinent publications in the coral reef monitoring domain, encompassing both automated and non-automated approaches. This exhaustive review of the state-of-the-art literature enhances comprehension while delineating the evolutionary trajectory of the field.

Understanding the current landscape of coral monitoring systems is paramount, necessitating an examination of prevailing constraints, challenges, and promising breakthroughs. Moreover, identifying cost-effective equipment capable of autonomous monitoring is pivotal, laying the groundwork for developing a Meteoceanographic Buoy prototype engineered for minimal human intervention.

Prototyping the Buoy demands meticulous consideration of cost-effectiveness, longevity, self-sufficiency, and seamless integration with extant networks. Essential components include sensors for salinity, temperature, and oxygen levels, complemented by an integrated battery system.

The project initiates with a laboratory testing phase, wherein components are assembled and integrated. Here, the functionality of salinity, temperature, and oxygen sensors is scrutinized, alongside their interfacing with the data-sharing electronic platform.

Subsequently, the prototype undergoes field testing to evaluate its performance under real-world marine conditions. This stage is pivotal for assessing durability against wave impact and seawater corrosion. Additionally, field tests facilitate the collection of authentic data to validate the sensors' accuracy and reliability.

Results and Discussion

The proposed device consists of a floating buoy composed of sturdy and lightweight materials capable of withstanding marine conditions such as wave impact and corrosion caused by seawater. The Buoy should be equipped with strategically positioned sensors, including a salinity sensor, a temperature sensor, and an oxygen sensor (Figure 1).

The submerged section of the buoy houses all the essential sensors, enabling the monitoring of various parameters near coral reefs. An Arduino (ATmega328) is the electronic prototyping platform atop the Buoy, complemented by a GSM module (sim900a) for internet-enabled data transmission.

Instead of a galvanic sensor, an optic sensor (DOG-209FYD) is employed for monitoring dissolved oxygen, owing to its enhanced reliability and non-toxic properties. Salinity measurements are facilitated by an electrical conductivity sensor (RK500-13), renowned for its seamless integration and low power consumption. Meanwhile, temperature monitoring is entrusted to the DS18B20 sensor, which is esteemed for its affordability and dependable performance. Figure 2 presents these sensors.

Near the Buoy's apex, a compact solar panel links to a base-mounted battery, forming an energy storage system vital for continuous operation. This

Figure 1. Meteoceanographic buoy and Sensor tray.

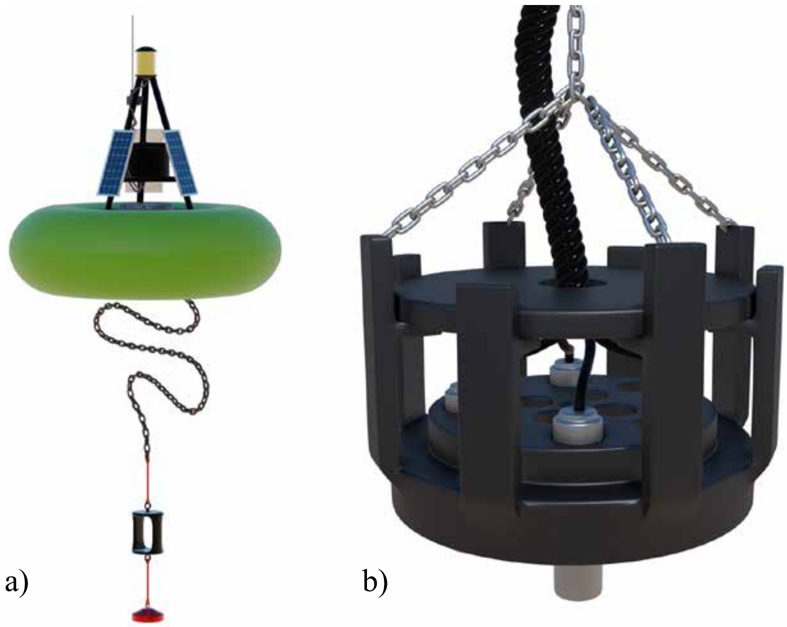

Figure 2. Respectively: RK500-13, DS18B20, DOG-209FYD.

setup harnesses solar energy during daylight for subsequent use during diminished solar exposure and nighttime periods.

It is securely housed within a sealed enclosure to safeguard the battery from external elements such as water, sunlight, and wind. Data transmission occurs at short intervals, approximately every 10 minutes when internet-connected, with immediate transmission triggered by significant environmental shifts. This strategy conserves battery power, mitigating depletion risks arising from constant connectivity and computation and minimizing the potential for data loss during periods of inactivity.

The Buoy's rounded base offers stability against ocean currents, while its elongated top features a small antenna, indicating the sensor's internet connectivity and data transmission functions.

At the Buoy's core lies a sealed compartment housing the battery. Submerged beneath the surface, a 3-meter cable connects the structure to a protective "cage" shielding the sensors from direct marine animal contact, housing all submerged sensors as illustrated in Figure 1.

This robust design ensures the Buoy's resilience in marine environments, facilitating the acquisition and transmission of critical water quality data from the coral reef vicinity, thus bolstering ecosystem preservation efforts.

The sensors are tethered by a chain beneath the Buoy, with wiring routed through it, bolstering their security and stability. This configuration ensures their connectivity to the Buoy and maintains their positioning within the data collection radius, minimizing deviations caused by water currents. Consequently, this setup enhances data accuracy and diminishes the risk of buoy dislodgement, fortifying the system's reliability. Thus, the chain and wiring amalgamation is indispensable in sensor safety and performance.

Conclusion

Various challenges associated with establishing an automated monitoring system and marine preservation have been elucidated through the research and conceptualization phases. A primary challenge lies in determining the optimal sensor placement on the Buoy to ensure accurate monitoring of water parameters near coral reefs.

Integrating the battery into the system is critical, necessitating meticulous isolation from environmental elements due to its susceptibility to damage.

Concerning automated monitoring, careful consideration must be given to defining the frequency and data size for transmission, typically around 10 Kb per transfer, equivalent to approximately 10,000 characters. This decision balances energy consumption, data usage, and information accuracy.

Ultimately, the automated monitoring system facilitates continuous data collection on water quality parameters near coral reefs, enabling real-time analysis. This capability can significantly contribute to coral preservation efforts by facilitating prompt responses to environmental threats.

Moreover, the incorporation of solar energy and optimization of data transmission enhance the system's efficiency, reliability, and autonomy, bolstering its effectiveness in marine conservation endeavors.

References

1. Cole J, Pratchett MS, Jones GP. Diversity and functional importance of coral-feeding fishes on tropical coral reefs. Fish and Fisheries 2008;9(3):286-307. Available at: <https://doi.org/10.1111/j.1467-2979.2008.00290.x>.
2. Wulff J. Assessing and monitoring coral reef sponges: Why and how? Bulletin of Marine Science, Miami, 2001;69(2):831-846. Available at: <https://www.researchgate.net/publication/233669506_Assessing_and_monitoring_coral_reef_sponges_Why_and_how>.
3. Obura DO et al. Coral reef monitoring, reef assessment technologies, and ecosystem-based management. Frontiers in Marine Science 2019;6. Available at: <https://www.frontiersin.org/articles/10.3389/fmars.2019.00580>.
4. Manderson T et al. Robotic coral reef health assessment using automated image analysis. Journal of Field Robotics 2017;34(1):170-187. Available at: <https://doi.org/10.1002/rob.21698>.