AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 05 Issue: 08 August 2024 Article No: 09

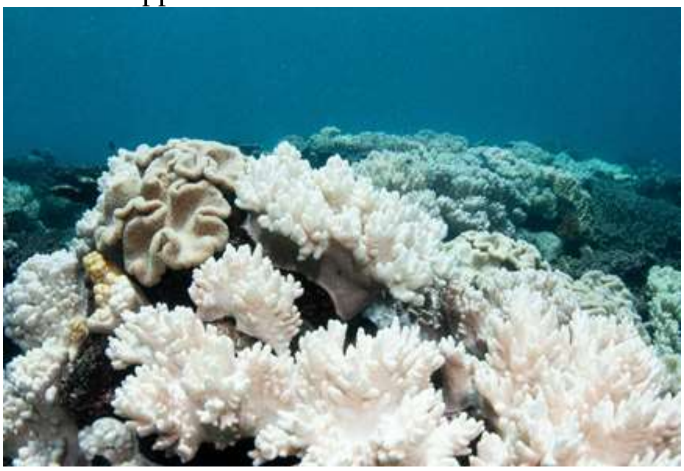
Innovative Technologies to Monitor and Predict Coral Bleaching

Shrivasanthan K K[1], Arivukumar E[2] and Mohamed Rizwan K[3]
[1]M.FSc Student, Department of Aquatic Environment Management, Fisheries College and Research Institute, Thoothukudi
[2]M.FSc. Student, Department of Fish Quality Assurance and Management, Fisheries College and Research Institute, Thoothukudi
[3]M.FSc. Student, Department of Fish processing Technology, Fisheries College and Research Institute, Thoothukudi

SUMMARY
Innovative technologies are revolutionizing coral reef conservation efforts. Satellite monitoring, drone imagery, and underwater robotics provide unprecedented insights into reef health, while AI and predictive modelling enhance our ability to assess and forecast coral bleaching events. These advancements enable more timely and targeted interventions, crucial in the face of intensifying climate change threats. By embracing these technologies, conservationists are better equipped to protect these vital ecosystems for future generations, though challenges in data quality, model interpretation, and resource allocation remain. Continued innovation and investment in these fields are essential for the effective preservation of coral reefs worldwide.

INTRODUCTION

Coral reefs, often called the rainforests of the sea, are among the most diverse and valuable ecosystems on Earth. However, these underwater marvels face an increasing threat from coral bleaching, a phenomenon that has become more frequent and severe in recent decades. Coral bleaching occurs when corals expel the colourful algae (zooxanthellae) living in their tissues, exposing their white skeleton. This symbiotic relationship between corals and zooxanthellae is crucial for the coral's survival, as the algae provide up to 90% of the coral's energy. When corals experience stress, primarily from elevated water temperatures, they expel these algae, leading to the characteristic white appearance of bleached corals.



The primary driver of coral bleaching is climate change, which causes rising ocean temperatures. Other factors such as ocean acidification, pollution, and excessive sunlight exposure can exacerbate the problem. As global temperatures continue to rise, bleaching events have become more frequent and widespread. The 2016-2017 global bleaching event, for instance, affected reefs worldwide, with some regions experiencing up to 90% coral mortality. The impacts of coral bleaching extend far beyond the aesthetic loss of colourful reefs. Bleaching can lead to reduced coral growth, increased susceptibility to diseases, and, if prolonged, coral death. This, in turn, affects the entire reef ecosystem, as countless marine species rely on corals for food, shelter, and breeding grounds. The decline of coral reefs also has significant economic implications, threatening the livelihoods of millions who depend on these ecosystems for fishing and tourism.

Given the critical importance of coral reefs and the escalating threat of bleaching, monitoring and predicting these events has become crucial. Early detection allows for rapid response and implementation of conservation measures, potentially mitigating the worst impacts of bleaching. By understanding bleaching patterns and trends, scientists can identify vulnerable reef areas and track the progression of events over time. This information is vital for assessing overall marine ecosystem health and biodiversity. Moreover, accurate monitoring and prediction of coral bleaching inform policy and management decisions. Data-driven approaches can guide the design of marine protected areas, shape climate change mitigation strategies, and help coastal communities prepare for potential economic impacts. As the frequency and intensity of bleaching events increase, the ability to forecast and respond to these incidents becomes ever more critical. Recognizing this need, the field of coral reef monitoring has seen significant technological advancements in recent years. Traditional methods of manual, diver-based surveys are being supplemented and, in some cases, replaced by innovative high-tech solutions. These new technologies allow for more comprehensive, frequent, and cost-effective monitoring of coral reefs on a global scale. Remote sensing technologies, including satellite-based systems and aerial drones, now provide researchers with the ability to observe vast reef areas regularly. Underwater technologies such as autonomous vehicles and advanced imaging systems offer detailed, close-up views of coral health. The integration of artificial intelligence and machine learning has revolutionized data processing and analysis, enabling rapid assessment of coral condition and prediction of bleaching risks. Real-time monitoring systems and early warning networks are being developed, combining various data sources to provide comprehensive and timely information on reef health. Furthermore, collaborative platforms and global databases are fostering international cooperation in coral reef research and conservation efforts. As we face the growing challenge of coral bleaching, these technological innovations offer hope. By enhancing our ability to monitor and predict bleaching events, they provide valuable tools in the fight to preserve one of Earth's most precious and vulnerable ecosystems. The following sections will delve deeper into these cutting-edge technologies and their applications in coral reef conservation.

Remote Sensing Technologies

Satellite-based monitoring

Satellite-based monitoring has transformed large-scale coral reef observation. This technology allows for continuous, global coverage of reef systems, providing crucial data on environmental conditions that affect coral health.

a.NOAA's Coral Reef Watch

NOAA's Coral Reef Watch program is a cornerstone of satellite-based coral monitoring. This program utilizes data from various satellites to provide near real-time monitoring of reef environments worldwide. It offers products such as sea surface temperature maps, bleaching alert areas, and coral bleaching heat stress gauges. These tools enable researchers and reef managers to identify potential bleaching hotspots and implement proactive conservation measures.

b. AVHRR

The Advanced Very High Resolution Radiometer (AVHRR) is a key instrument in satellite-based coral monitoring. Carried on NOAA's polar-orbiting satellites, this scanning radiometer measures the Earth's surface temperature with high precision. The AVHRR can detect temperature changes as small as 0.1°C, which is crucial for identifying the slight increases in water temperature that can trigger coral bleaching. Its global coverage and frequent revisit times (typically twice daily) provide a comprehensive view of oceanic conditions affecting coral reefs worldwide.

Drone technology

Drone technology offers a middle ground between satellite imagery and in-situ observations, providing high-resolution data for specific reef areas.

a. High-resolution aerial imagery captured by drones allows for detailed mapping of reef structures and coral health. Unmanned Aerial Vehicles (UAVs) equipped with high-resolution cameras can survey large reef areas quickly and cost-effectively. These images, when stitched together, create detailed maps that can track changes in reef composition and health over time.

b. Thermal mapping of coral reefs using drones equipped with thermal cameras is an emerging technique. These thermal sensors can detect subtle temperature variations across reef surfaces, potentially identifying areas of thermal stress before visible signs of bleaching appear. This capability is crucial for early intervention. Thermal mapping can also reveal patterns of water circulation and identify cooler refugia within reef systems, which could be critical for coral survival during heat stress events.

Underwater robotics

Underwater robotics represents the cutting edge of coral reef monitoring technology, allowing for detailed, up-close observation of reef ecosystems.

a.AUVs

Autonomous Underwater Vehicles (AUVs) are being deployed to conduct comprehensive surveys of reef health. These self-propelled robots can navigate independently, following pre-programmed routes to collect data on water quality, temperature, and even capture high-resolution images of coral colonies. AUVs can operate at various depths and cover large areas, providing a three-dimensional understanding of reef environments.

b. Specialized reef-monitoring robots

Specialized reef-monitoring robots are being developed for specific tasks. For example, the COTSbot is designed to detect and control outbreaks of crown-of-thorns starfish, a significant threat to coral reefs. Other robots are equipped with sophisticated imaging systems that can capture microscopic details of coral polyps, helping to detect early signs of stress or disease. These specialized robots complement broader survey efforts and can perform tasks that would be difficult or dangerous for human divers.

AI and Predictive Modelling

AI and Predictive Modelling have become integral to coral reef conservation efforts, offering powerful tools for assessing coral health, predicting bleaching events, and developing early warning systems. These technologies are revolutionizing our approach to coral reef management and protection.

Machine learning algorithms for coral health assessment

Machine learning algorithms are increasingly being applied to assess coral health at unprecedented scales and speeds. These algorithms can analyse vast amounts of data from various sources, including satellite imagery, underwater photographs, and spectral data. One significant application is in automated image analysis. Researchers have developed convolutional neural networks (CNNs) that can accurately identify different coral species, detect signs of bleaching, and even recognize coral diseases from underwater imagery. These algorithms can process thousands of images in a fraction of the time it would take human experts, greatly expanding our capacity to monitor reef health. For example, the CoralNet platform uses deep learning algorithms to annotate coral survey images automatically. This tool has dramatically reduced the time required for image analysis, allowing researchers to focus on interpretation and decision-making rather than tedious manual annotation. Machine learning is also being used to analyze hyperspectral data from coral reefs. These algorithms can detect subtle changes in coral color that might indicate the early stages of bleaching, even before it's visible to the human eye. This early detection capability is crucial for timely intervention.

Predictive modelling using big data

Big data analytics and predictive modelling are enhancing our ability to forecast coral bleaching events and understand long-term trends in reef health. These models integrate diverse data sources, including historical temperature records, ocean current patterns, climate models, and coral bleaching observations. NOAA's Coral Reef Watch program, for instance, uses a combination of satellite data and modelling to predict potential bleaching events up to four months in advance. Their model considers factors such as sea surface temperature, solar radiation, and wind patterns to generate bleaching outlook products. More sophisticated models are being developed that incorporate additional variables like ocean acidification, pollution levels, and even genetic data on coral resilience. These complex models aim to provide a more nuanced understanding of coral reef dynamics and improve long-term predictions of reef health.Machine learning techniques like random forests and gradient boosting are being employed to identify the most important predictors of coral bleaching. These approaches can uncover complex relationships in the data that might not be apparent through traditional statistical methods.

Early warning systems

The integration of AI and predictive modelling has led to the development of advanced early warning systems for coral bleaching. These systems aim to alert reef managers and conservationists to potential bleaching events in time for preventive action. One example is the Allen Coral Atlas, which combines satellite imagery, machine learning, and in-water observations to create a near real-time monitoring system for the world's coral reefs. The system can detect changes in reef composition and warn of potential bleaching events. Another innovative approach is the use of environmental DNA (eDNA) analysis combined with AI. By analysing the genetic material present in water samples, researchers can assess biodiversity and detect stress signals in coral communities. Machine learning algorithms can then process this data to provide early warnings of ecosystem changes.

Future prospects and challenges

The future of AI and predictive modelling in coral reef conservation is promising, with several exciting developments on the horizon:

- Integration of multi-scale data: Future models will likely incorporate data from various scales, from satellite observations down to microbial community analyses, providing a more comprehensive understanding of reef health.
- Real-time adaptive modelling: As computational power increases, we may see the development of models that can adapt in real-time to changing conditions, providing even more accurate predictions.
- Personalized reef management: AI could enable more tailored conservation strategies, considering the unique characteristics and vulnerabilities of individual reef systems.

However, several challenges remain:

- Data quality and standardization: Ensuring consistent, high-quality data across different regions and time periods is crucial for accurate modelling.
- Model interpretability: As models become more complex, ensuring that their predictions are interpretable and actionable for reef managers becomes increasingly important.
- Ethical considerations: The use of AI in conservation raises questions about data privacy, especially when working with indigenous communities or in sensitive areas.
- Resource limitations: Many regions lack the technological infrastructure and expertise to implement advanced AI systems, potentially leading to disparities in conservation efforts.

CONCLUSION

The landscape of coral reef conservation has been radically transformed by cutting-edge technologies. Remote sensing tools, from satellites to underwater robots, now provide unprecedented insight into reef health. Simultaneously, AI and predictive modelling have revolutionized our ability to assess, forecast, and respond to threats like coral bleaching. These innovations are not just improving our understanding; they're enabling more timely and targeted interventions. As climate change intensifies the threats to coral reefs, continued technological innovation becomes ever more crucial. Advancements in these fields are making conservation efforts more effective and accessible globally. The race to save coral reefs demands that we push the boundaries of what's possible in conservation technology. By embracing and investing in these innovations, we significantly improve our chances of preserving these vital ecosystems for future generations.

REFERENCES

González-Rivero, M., Beijbom, O., Rodriguez-Ramirez, A., Holtrop, T., González-Marrero, Y., Ganase, A., ... & Hoegh-Guldberg, O. (2016). Scaling up ecological measurements of coral reefs using semi-automated field image collection and analysis. Remote Sensing, 8(1), 30. https://doi.org/10.3390/rs8010030

Hedley, J. D., Roelfsema, C. M., Chollett, I., Harborne, A. R., Heron, S. F., Weeks, S., ... & Mumby, P. J. (2016). Remote sensing of coral reefs for monitoring and management: a review. Remote Sensing, 8(2), 118. https://doi.org/10.3390/rs8020118

Levy, J., Hunter, C., Lukacazyk, T., & Franklin, E. C. (2018). Assessing the spatial distribution of coral bleaching using small unmanned aerial systems. Coral Reefs, 37(2), 373-387. https://doi.org/10.1007/s00338-018-1662-5

Liu, G., Eakin, C. M., Chen, M., Kumar, A., De La Cour, J. L., Heron, S. F., ... & Strong, A. E. (2018). Predicting heat stress to inform reef management: NOAA Coral Reef Watch's 4-month coral bleaching outlook. Frontiers in Marine Science, 5, 57. https://doi.org/10.3389/fmars.2018.00057

Obura, D. O., Aeby, G., Amornthammarong, N., Appeltans, W., Bax, N., Bishop, J., ... & Wongbusarakum, S. (2019). Coral reef monitoring, reef assessment technologies, and ecosystem-based management. Frontiers in Marine Science, 6, 580. https://doi.org/10.3389/fmars.2019.00580