

# IMPLEMENTATION OF AN ENVIRONMENTAL VARIABLE CONTROL SYSTEM FOR THE GROWTH OF GATORADE ZOAS CORAL

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**López Fierro Gerardo**

TecNM/Technological Institute of Ciudad  
Juárez <https://orcid.org/0000-0002-3847-0554>  
[Gerardo.lf@cdjuarez.tecnm.mx](mailto:Gerardo.lf@cdjuarez.tecnm.mx)

**González Muñoz Miriam Magdalena**

TecNM/Technological Institute of Ciudad  
Juárez <https://orcid.org/0009-0006-1163-5847>  
[miriam.gm@cdjuarez.tecnm.mx](mailto:miriam.gm@cdjuarez.tecnm.mx)

**Castañeda Fierro Francisco**

TecNM/Technological Institute of Ciudad  
Juárez <https://orcid.org/0009-0005-1858-5996>  
[francisco.cf@cdjuarez.tecnm.mx](mailto:francisco.cf@cdjuarez.tecnm.mx)

**Camarillo Delgadillo José Mario**

TecNM/Technological Institute of Ciudad  
Juárez <https://orcid.org/0000-0003-1446-8950>  
[jose.cd@cdjuarez.tecnm.mx](mailto:jose.cd@cdjuarez.tecnm.mx)

**Ríos Fernández Nancy Esperanza**

TecNM/Technological Institute of Ciudad  
Juárez <https://orcid.org/0009-007-5289-8202>  
[Nancy.rf@cdjuarez.tecnm.mx](mailto:Nancy.rf@cdjuarez.tecnm.mx)



**Abstract:** An automated system was developed to control environmental variables in order to promote the growth of Gatorade Zoas coral. The system precisely regulates light, temperature, water flow, pH, salinity, and alkalinity, creating an ideal controlled environment for coral development. This technological solution reduces the need for prior experience in coral cultivation, facilitating satisfactory results even for non-specialized users. In addition, the data collected during the growth process will be used to establish optimal parameters that contribute to the study and conservation of this species.

**Keywords:** coral cultivation, automation, environmental variables, Gatorade Zoas, control systems.

**Abstract:** An automated system was developed to control environmental variables that promote the growth of Gatorade Zoas coral. The system accurately regulates light intensity, temperature, water flow, pH, salinity, and alkalinity, creating a controlled environment ideal for coral development. This technological solution minimizes the need for prior experience in coral cultivation, enabling satisfactory outcomes even for non-expert users. Furthermore, the data collected during the growth process will support the identification of optimal parameters, contributing to the study and conservation of this coral species.

**Keywords:** coral cultivation, automation, environmental variables, Gatorade Zoas, control systems.

## INTRODUCTION

The art of preserving marine life is increasingly intertwined with technology. This article presents the development and implementation of an automated control system, considering certain environmental variables, designed to promote the growth of Gatorade Zoas coral in artificial environments, such as fish tanks or aquariums. This project arose from the need to conserve vulnerable marine species (Reyes, 2010; Gutiérrez, 2012), proposing an alternative that combines science, engineering, and ecological commitment.

Through the use of microcontrollers, temperature, pH, lighting, and water flow sensors, a controlled environment has been created that emulates the ideal conditions of tropical reefs. The system not only facilitates the monitoring and care of corals by inexperienced users, but also represents a possibility for use for educational, commercial, or conservation purposes.

In Ciudad Juárez, there is a community that works with marine aquariums, and their maintenance and adaptation is very costly. A key element for this type of aquarium is Gatorade Zoas coral, which is difficult to handle and transport to the city. The design of this system will allow cultivation under environmentally induced conditions through an automated system for controlling physicochemical variables to achieve the reproduction of this type of coral, thus providing the option of marketing cultivated coral.

### **General objective**

To design a system for controlling certain environmental variables that provides the ideal conditions for the proper growth and reproduction of Gatorade Zoas coral in an aquarium.

### **Specific objectives**

- To determine the ideal environmental conditions for coral growth.
- Identify the sensors and actuators that will be involved in the model.
- Establish the programming language to be used to control the system.
- Identify the logical circuit structures necessary for the physical control of the system.
- Design the system structure within 3D design simulators.
- Create circuit structure designs within electrical and/or electronic simulation programs.
- Develop a functional prototype of the environmental variable control system.
- Conduct tests prior to its installation in the fish tank with regard to the control of environmental variables.
- Implement the prototype of the control system in the fish tank.

### **Justification**

The development of an automated system for controlling environmental variables in aquariums is an innovative solution to the growing deterioration of coral ecosystems. Corals, especially those belonging to the Zoanthidae family such as Gatorade Zoas, are organisms that are extremely sensitive to variations in parameters such as temperature, pH, salinity, lighting, and water flow. These factors must be maintained within very specific ranges to allow for their survival and growth (Reyes, 2016; Arteaga, 2018).

This project proposes a viable technological alternative for creating a controlled ex situ environment, thereby enabling coral reproduction and conservation in unfavorable urban contexts such as Ciudad Juárez, where natural environmental conditions are not optimal for coral development (Arteaga, 2018). Through the use of Arduino microcontrollers, digital sensors, and programmable control systems, a platform was designed that can automatically regulate the internal conditions of a fish tank with minimal human intervention, promoting coral care even by users without specialized knowledge (Culkin, 2021; Sánchez, 2019).

The automation of this type of system also represents an educational, ecological, and commercial opportunity. On the one hand, it allows students and the general public to learn about marine preservation issues through the application of electronics and programming knowledge. On the other hand, it offers a scalable model that can be implemented in small businesses or conservation projects, facilitating coral reproduction in controlled environments without the need to import expensive technologies (Pérez, 2015; Giancoli, 2005).

In a global context where coral reefs are endangered by climate change and ocean acidification, initiatives such as this represent an important step towards sustainability and local technological appropriation with a positive environmental impact.

## DEVELOPMENT

### Coral growth

The growth of Gatorade Zoas coral is influenced by various environmental and chemical variables, including alkalinity, temperature, light incidence, type of light incidence, pH, water flow, and salinity. The ideal conditions for growth are shown in Table 1.

**Table 1.** *Coral growth variables.*

Variables ambientales/químicas	Valores aceptados
Alcalinidad	125-200 ppm / 7-8 dKH
Temperatura	19 – 29 °C
Incidencia de luz	100 – 250 PAR
Tipo de luz	T5's, Metal Halides, o LED's
PH	8 PH
Flujo de agua	Baja - Moderada
Salinidad	1023g – 1026 g / 34 – 38 ppt

Source: Jaques, T. (2003).

The control of each of these variables will be explained below:

**System brightness control.** Before designing the control, it is necessary to know the light spectrum for coral growth; from various studies on the light spectrum, it has been deduced that lights with wavelengths between 370 and 500 nm are excellent for penetrating deep into the water. This type of light in this wavelength range includes violet and blue parts of the light spectrum, both of which should easily penetrate seawater to reach coral reefs for better growth. (Pérez, 2015)

Light control was achieved using a strip of LEDs (5050 SMD), powered by a 12 Vdc source, which provides blue, green, and red (RGB) light colors. The LEDs are controlled by an Arduino Uno microcontroller, which provides the necessary combination and range of light tones.

**Water movement.** Lack of water circulation can cause coral to suffocate, while unidirectional currents can cause coral to become irritated and close up. Wave generators help eliminate these problems and improve the health and growth of the tank's inhabitants. The water in an aquarium should have moderate to high movement for *Zoanthus* corals, as water movement allows for greater light flow, which can reach the coral. However, corals do not survive in areas of tropical lagoons that are exposed to sunlight during low tide, as this acts as a brake on their growth due to prolonged exposure to air.

The movement of the water is generated using a wave generator, regulated by a light attenuator that allows us to control the speed of the motor. The on-off function is controlled and programmed using Arduino. In this case, servomotor control logic will be used to indicate the zero crossing point, thereby ensuring that the requested speed is calculated correctly. (Ortiz, 2021)

**Temperatures.** Coral reefs are found all over the world between 30 degrees north latitude and 30 degrees south latitude, so water temperature and depth determine the distribution and growth of coral reefs, because the small marine organisms that build reef structures need to live in warm waters; Therefore, the water temperature should not fall below 23 degrees Celsius for prolonged periods. (Magnason, 2021).

The temperature variable is controlled by the DS18B20 digital sensor, which provides accurate readings of the current water temperature in the fish tank. To keep this variable within an optimal range, two main thermal control mechanisms are implemented:

**Aquarium water heater:** Activated when the temperature falls below the pre-set threshold value. Its function is to stabilize the internal temperature of the aquarium, preventing the water from cooling excessively.

**Cooling fan:** Operates in the opposite way to the heater. It is activated when the temperature exceeds the upper limit of the permitted range, promoting water evaporation, which generates natural heat loss and helps to reduce the temperature. To maximize its efficiency, the fan should be placed as close as possible to the water surface.

Both devices are managed by two control relays, which allow each system to be turned on and off automatically based on sensor readings. The control logic is implemented in an Arduino Uno microcontroller, which acts as the central unit of the system, processing sensor signals and activating the corresponding actuators to maintain the temperature within the desired range.

**Water pH.** pH is a measure that indicates the acidity or alkalinity of water. It is defined as the concentration of hydrogen ions in water. The pH scale is logarithmic with values from 0 to 14. An increase of one unit on the logarithmic scale is equivalent to a tenfold decrease in the concentration of hydrogen ions. With a decrease in pH, the water becomes more acidic, and with an increase in pH, the water becomes more basic (Silverthorn, 2008).

Controlling the pH of the water in the fish tank begins with the use of a pH measuring electrode, which detects the level of acidity or alkalinity of the water in real time. This sensor allows you to know if the pH value is within the optimal range for aquatic life or if it requires correction.

To adjust the pH according to the system's needs, there are two containers that store chemical solutions: one to increase alkalinity and another to reduce it (i.e., increase acidity). These substances are dosed using two solenoid valves, each connected to a container, which allow for the precise release of the corresponding chemical.

The system is controlled by an Arduino Uno microcontroller, which:

- Processes the readings from the pH electrode,
- Determines whether a correction towards more acidic or more alkaline values is required,

- Activates the corresponding solenoid valve,
- Controls the valve opening time to ensure proper dosing.

This mechanism allows the pH of the water to be maintained within the desired limits, thus ensuring a stable and healthy environment for aquatic organisms.

## DISCUSSION AND ANALYSIS OF RESULTS

The implementation of the automated environmental variable control system for the growth of Gatorade Zoas coral has proven to be a functional, accurate, and low-cost solution for the reproduction of this type of organism in artificial environments. The regulation of critical parameters such as light intensity, water movement, temperature, and pH allowed stable conditions to be maintained that simulate the natural habitat of Gatorade Zoas corals, resulting in an environment conducive to their growth and survival.

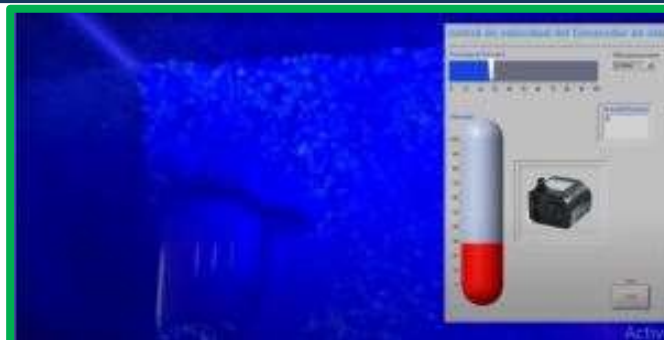
The results obtained, shown in Figures 1, 2, 3, and 4, demonstrate effective control of each monitored variable. In the case of luminosity (Figure 1), an adequate light spectrum was maintained in the blue-violet range (370–500 nm), which is key for photosynthesis in the zooxanthellae present in the coral. This control contributed directly to the constant opening of the polyps and improved pigmentation of the coral tissue.



**Figure 1.** *Sample data on luminosity.*

**Source:** *Own elaboration (2025).*

In terms of water flow (Figure 2), the use of a programmable wave generator made it possible to simulate natural ocean currents. This water dynamics not only improved oxygenation of the environment, but also prevented the accumulation of debris and promoted healthy interaction between the coral and its surroundings.



**Figure 2.** *Wave generator data.*

**Source:** *Own elaboration (2025).*

With regard to temperature (Figure 3), the DS18B20 sensor regulation system, together with the heating and cooling mechanisms, kept the water within the ideal range of 24 to 27 °C. This was key to ensuring the metabolic stability of the coral and preventing thermal stress conditions.



**Figure 3.** *Temperature control.*

**Source:** *Own elaboration (2025).*

The overall analysis indicates that the developed system not only achieved its objectives but also proved to be replicable and adaptable. Furthermore, its ease of use is a significant advantage for users without prior technical experience, which broadens its potential applications in educational, domestic, or conservation settings.

Figure 4 shows the physical layout of the components that make up the pH variable control system in the experimental prototype. The servomotor is installed at an intermediate height between the fish tank and the body of water, in order to prevent mechanical or electrical damage resulting from exposure to the liquid medium. A dispensing tube is located at the top of the servomotor, which acts as a conduit for dosing the pH-regulating chemical agent. On the other hand, the pH electrode is submerged in the water, a necessary condition to ensure accurate, real-time measurement of this variable.



**Figure 4.** *pH control.*

**Source:** *Own elaboration (2025).*

### **Comparison with previous studies**

The results obtained in this project partially agree with the findings of Arteaga (2018), who highlighted the importance of maintaining stable levels of alkalinity and calcium for coral growth in reef aquariums. In the present system, automatic pH and temperature measurements allow for more precise control of these conditions, optimizing the physiological response of the coral without requiring constant manual intervention.

Similarly, Sánchez (2019) developed a temperature monitoring system based on the DS18B20 sensor with Arduino, achieving efficient thermal control in aquatic environments. However, the system proposed in this work extends this application by integrating the simultaneous regulation of multiple variables (light, water flow, and pH), representing a significant step toward comprehensive automated control.

Finally, Pérez (2015) analyzed the most suitable light spectrum for the photosynthesis of zoanthid corals, determining that wavelengths between 370 and 500 nm favor pigmentation and growth. In line with this, the system developed in this study uses RGB LED lighting within that range, experimentally corroborating the effectiveness of blue-violet light in the development of Gatorade Zoas coral.

### **CONCLUSIONS**

The automated system implemented to control environmental variables represents a significant advance in the reproduction and ex situ conservation of Gatorade Zoas coral. Through the use of specialized sensors and microcontrollers, optimal conditions of light, temperature, pH, and water flow were maintained, providing a stable environment for coral development even in unfavorable urban contexts.

This project demonstrates that it is feasible to integrate low-cost, easily accessible technologies to automate sensitive biological processes, reducing dependence on advanced technical knowledge and making implementation possible for novice users. In addition, the data obtained through continuous monitoring allows for the establishment of reference parameters that could be applied in future research on coral aquaculture.

The replicable and educational approach of the designed system makes it a useful tool not only for responsible aquarium keeping, but also for educational institutions and marine restoration projects. In short, this proposal offers a sustainable technological solution with a positive environmental impact and potential for scaling up in different regions of the country.

### **FUTURE WORK**

The system operates automatically, but it requires regular monitoring and maintenance to ensure that the control systems are functioning properly.

Improving the quality of the lighting will give the coral better coloration, therefore, the acquisition of higher performance lighting is recommended.

Although coral growth can be achieved with the variables under control, implementing another type of variable such as salinity will allow the coral to develop in a more optimal environment, reducing the risk of inadequate growth.

It is also suggested that field tests be conducted to validate the robustness of the system under real aquarium conditions.

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## COLLABORATIVE WORK TABLE

Role	Author(s)
Conceptualization	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Gerardo López Fierro
Method	Miriam Magdalena González Muñoz, Gerardo López Fierro
Software	Miriam Magdalena González Muñoz, Gerardo López Fierro
Validation	Nancy Esperanza Ríos Fernández, Gerardo López Fierro

Formal Analysis	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Nancy Esperanza Ríos Fernández
Research	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Gerardo López Fierro
Resources	Gerardo López Fierro, José Mario Camarillo Delgadillo
Data curation	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Nancy Esperanza Ríos Fernández, Gerardo López Fierro
Writing - Preparation of the original draft	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Gerardo López Fierro
Writing - Revision and editing	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, José Mario Camarillo Delgadillo
Visualization	Gerardo López Fierro
Supervision	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, José Mario Delgadillo Camarillo
Project Management	Miriam Magdalena González Muñoz, Francisco Castañeda Fierro, Nancy Esperanza Ríos Fernández, Gerardo López Fierro
Acquisition of funds	Gerardo López Fierro, José Mario Camarillo Delgadillo