

Full Circle Coral

Life Below Water: UN Sustainable Development Goal 14

Sylvia Joseph

University of Illinois Chicago, sjosep34@uic.edu

Tim Behland

University of Illinois Chicago, tbehla2@uic.edu

Megan Herrera

University of Illinois Chicago, mherre42@uic.edu

Corals are one of the ocean's most vibrant and diverse creatures. However, coral reefs are in some of the most danger due to threats such as climate change and pollution, which contribute to coral bleaching and reef degradation. Full Circle Coral is a virtual reality experience developed for the CAVE2™ Virtual Environment that has users swim through the life cycle of a coral reef. The concept of this project is to help users understand the enormity of the threats that coral reefs face, the importance of protecting them, and promote research into reef conservation. The “deep dive” experience will walk users through the growth and death of coral reefs and what contributes to each stage.

Additional Keywords and Phrases: Virtual Reality, CAVE2, Coral Reef, Sustainability, Coral Bleaching, Conservation

ACM Reference Format:

Sylvia Joseph, Tim Behland, and Megan Herrera. 2023. The Full Circle Coral: Life Below Water: UNSustainable Development Goal 14.

1 RESEARCH

This project was developed in collaboration with global IBM Design+Technology+Theater Group and developed in the Electronic Visualization Laboratory (EVL) at the University of Illinois Chicago.

The official theme that our team addressed is UN Sustainable Development Goal 14: Life Below Water. The UN describes this as the goal to “conserve and sustainably use the oceans, sea, and marine resources for sustainable development” [1]. This goal recognizes that life below water is closely linked to human activities and the well-being of coastal communities. “[D]irect exploitation of organisms, habitat degradation and climate change” have led to a sizeable decrease in marine life since 1977 [2]. Increasing acidification, plastic pollution, over-fishing, and ocean warming are some of the other problems endangering the ocean, which is “the planet’s largest ecosystem” [1]. Only three countries to date have successfully reached the requirements of this development goal [1].

1.1 The problem

A specific part of the ocean ecosystem that is especially impacted by these threats is coral. Corals are aquatic animals that have “plant-like cells living inside of [them]” [3]. Coral reefs are colonies of corals that continue to grow and build on older corals [4]. Reefs serve as habitats for marine life such as fish, sponges, crabs, and sea stars [5]. Coral reefs can become stressed by foreign materials that humans introduce such as toxins, pollutants, and destructive fishing and boating practices. When placed under excessive stress, coral reefs undergo a process known as coral bleaching, where they expel symbiotic algae that they host, and they become increasingly at risk of disease [4]. Since corals need sunlight to live, the excess of algae contributes to the reef's decay.

1.2 Solutions

To save dying reefs, scientists have developed techniques to efficiently propagate corals and replant them in a way that replenishes the dead coral reef. Some technologies in this process include coral nurseries where tiny, new corals are grown for divers to bring them underwater and strategically place them within a dying reef [6]. The divers also remove invasive species such as algae that are smothering the reef [7]. Biomaterials for replanting have also been experimented with. This includes materials like Biorock™ and Seament™ which are used to bind the new corals for faster growth and naturally reinforce the reef's natural strength [8]. Virtual solutions to this problem focus on immersing users through raw video footage that divers have collected of coral reefs. In order to enhance the experience, 360-degree cameras are also put into use [12]. National Geographic created a VR dive of the “beautiful and threatened” coral reefs of Palau [10]. A marine biologist from the University of Gothenburg is also investigating the effects of water immersion while exploring a VR underwater environment on the participants' emotional connection to the experience [11].

2 PROJECT IDEATION

The initial research phase of the project allowed for many ideation phases to take place starting with a basic coral introduction moving into a more conceptual day at the beach scenario. The ideation phases were a broad view into the development of a 3-dimensional world that showcases the existing coral problems upfront for users to discover and find possible solutions to. By introducing users to an ideal coral reef and allowing them the opportunity to see the damage that they actively cause, we can invoke positive feelings around the cleanup and replanting of coral in the ecosystem. We decided to title this project “Full Circle Coral” as it has users witness the life cycle of a coral reef, beginning and ending with the growth of new baby corals.

2.1 Storyboarding

By using a series of storyboards and pictography, the experience can be fully conceptualized in a 2-dimensional viewpoint, allowing for further research to be included in the development of the 3-dimensional world. Each storyboard hosts a unique take on a single scene and provides context into what the user will view and experience while traveling through the created world. Initial rough sketches provide the starting structure for each scene's development and for the testing of theoretical solutions to the coral problem. After initial sketches are completed, detail views are roughed out to give a more comprehensive view of specific details pertaining to each scene. The final iterations of the storyboards are created after each scene has gone through multiple revisions and all plausible solutions have been theorized and test fit into the user's journey. Once the final solution and path is chosen the final storyboard takes shape and uses not only pictography but color to coordinate each small detail about each scene that the user will journey through in the digital world. By noting all interactions and the detailed journey of the user we are able to develop a complex world that encompasses the best walkthrough for user feedback. The below Figure 1 shows a conceptual storyboard that allows the group to have a clear direction of where the project will be headed and what interactions will be featured in the project.

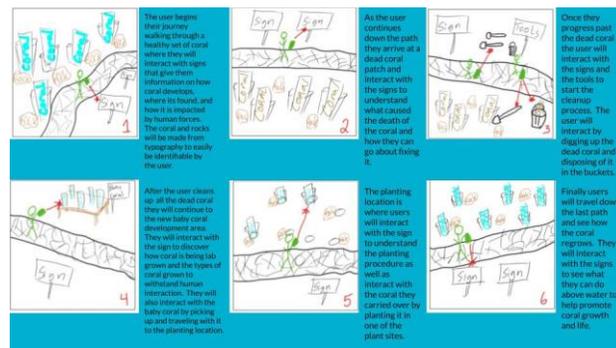


Figure 1: Final Iteration of Storyboard

2.2 Interactions

During early storyboard iterating we conceptualize interaction-based steps that the user must take in order for the user to complete their walkthrough of the digitally created world. Each scene hosts single or multiple complex interactions to fully immerse the user in the 3-dimensional world and to help show actual real-world involvement with the problem and solution demonstrated. By allowing the user a more open and freer to play interaction set the user is not directed but lightly guided to complete each step of a complex process. This allows the user to come to individual and self-assessed conclusions and actions during each integral scene. Furthermore, the open world allows for free willed thinking and exploration to openly develop ideas and solutions that are based on the premise of our initial solution. Thus, allowing for further development and exploration into the world of dying coral reefs and ways to prevent and regrow them in existing ecosystems.

3 DEVELOPMENT IN UNITY

For our storyboards to be realized, we utilized the Unity Game Engine to program the scenes and interactions of the simulation. The above Figure 1 was used as an initial base representation of the interactions and scenes needing to be developed in Unity. Fusion 360 was used to create 3D objects and typography. The development process in Unity focused on three main stages, sequencing the scenes for the user to experience, utilizing our 3D objects and typography to bring the scene to life, and lastly programming in the different interactions that the user can experience while learning about the current state of the coral reefs and what they can do to help.

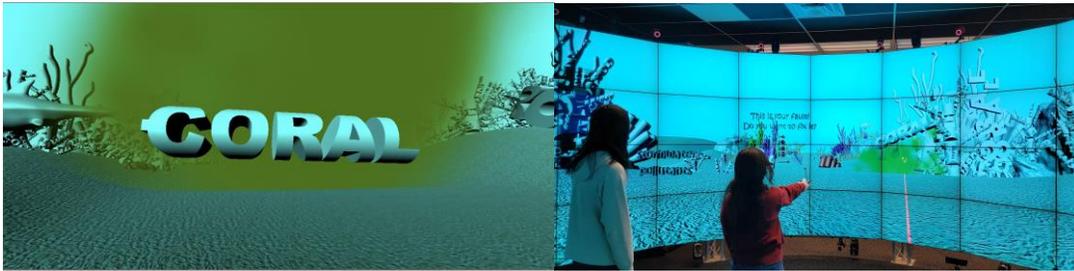
3.1 Scenes

The project consists of five main scenes. The user starts above the water on the beach near a beach hut. During this scene, the user can interact with different pollutants that are typically used on the beach, soda cans and sunscreen. After selecting the two objects, the user is then teleported to the next scene. In this scene, we present a serene image of a peaceful coral system filled with colorful coral, bubbles created with Unity's Particle System, fishes, and the calming sounds of the ocean playing in the background. The user can walk across this peaceful setting, but when they get to the end of the path, they are presented with the fact that this peaceful environment is not what the coral reefs currently look like. From here, the user is immediately teleported to our next scene. Here, the user is presented with a barren terrain, filled with bleached coral and overflowing algae, again created using Unity's Particle System, as shown in Figure 2. The user must "pull out" all the dead coral to disperse the algae, as shown in Figure 3. Once this task is complete, users can enter our next scene. During this scene, after learning that they played a part in harming the coral reefs, users are presented with our solution: growing artificial baby coral to replant in the location of dying coral reefs to help them come back to life. After completing the interactions in this scene, the user is then teleported back to the same location as the dead corals, but this time they will have the nursery of baby corals with them. During this last scene, the user can replant three corals. Each time they replant one coral, part of the coral reef will come back to life. Once the last coral reef is replanted, the user is presented with a thriving coral reef, with bubbles, colorful coral, and abundant marine life (Figure 4). This was done to show users how baby coral can change the dying ecosystem to a thriving one. In the case of this project, the baby coral's impact is seen almost immediately, but it will take time for changes to be seen after adding the baby coral.

The above water scene was given a beach-like terrain as well as a beach hut. This was done so the user feels like they're on the beach preparing for a dive. The remaining scenes take place underwater. To make it feel like one is underwater, the lighting of the scene was changed to blue so all objects in the scene appear bluish. Additionally, as discussed previously, different particle systems were used to emulate the underwater bubbles and algae to further represent the underwater location of the scenes. We used colors to differentiate between an alive coral and a dead coral. Colorful corals are alive ones, while white corals represented dead coral due to coral bleaching. The scenes follow these aesthetic choices until the very end, when the users get to see the result of their work. As shown in Figure 4, users will then encounter many alive

coral and different types of marine life swimming around. The addition of marine life is to indicate how the coral reefs have recovered and are now a suitable habitat for marine life again.

The sound design that we chose for this project was meant to emphasize the environment of each part of the life cycle. The experience begins with a calm underwater ambiance when the normal coral reef is shown. Once the dead reef is shown, the sound becomes underwater white noise to emphasize the silence associated with no marine life living in the reef. Finally, the scene ends with marine life returning to the reef and the sounds of dolphins and whales reflect the reef's revival.



Figures 2 & 3: Dead Coral Scene in Unity development and in CAVE2 environment.



Figure 4: VR Participants Encountering Final Message and Scene of a Lively Coral Reef.

3.2 3D Models and Typography

Throughout the project different 3D models and typography can be seen. The 3D models used were individual corals, coral reefs, fishes, crabs, and a shark. We used typography to represent individual corals and to display different facts and statistics to the users regarding the status of coral reefs. During the first iteration of the project, we only used typography to represent the corals. Initial feedback on this version of the prototype included the fact that the underwater environment seemed barren because of how spaced out the typography corals were from each other. To address this feedback, during the second iteration of the project, we combined 3D models of different coral reefs with our own typography to create one big coral reef object and included this in our project in the main coral reef scenes (the dead coral scene and the replanting

scene) as shown below in Figure 5. We also utilized 3D models to represent different marine life during various parts of the environment. Moving fish were present during the idealized version of the coral reef and both moving fish and crabs were a part of the thriving marine life at the end. A shark was also present during the dead coral scene and was eating all the fish that died from poor habitual environment caused by the coral bleaching and algae.

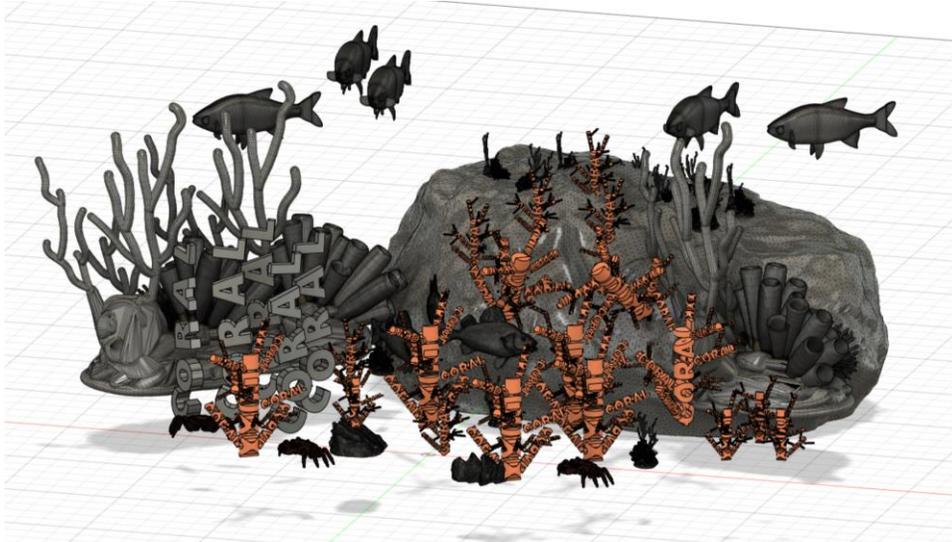


Figure 5: Fusion 360 Model

3.3 Virtual Interactions

There are four interactions presented in the program. The first interaction takes place in the first scene and involves the user selecting the different pollutants to use (e.g., taking a sip from the soda can and applying sunscreen). The second interaction takes place during the scene with the dead corals. Here, users must point and select the dead coral that they want to pull. This interaction represents the act of cleaning up the coral reefs, to remove the algae so we have space to plant later. As previously discussed, excess algae contribute to the coral reefs' decay due to the blockage of sunlight. By removing the algae, we start the process of helping the coral reefs. Users will also be presented with a fact about coral bleaching once the dead coral rises. The third interaction involves the user "clipping" (pointing and selecting) the baby corals to add them to the nursery where the baby coral can continue to develop until it is ready to be replanted. Every time the user clips a coral, a new statistic about coral nurseries rises from the sand to surround the user. The final interaction takes place when the users return to the location of the dead corals so they can plant the baby corals from the nursery. To perform this task, the users will press the arrow keys on the CAVE2 wand based on the location of the emitting particle system [9]. For example, if they see the particle system to the right of the user, they will press the right arrow key. These last two interactions make up the main part of our solution: creating coral nurseries so we can replant the baby coral to regrow the coral reefs.

When trying to decide how to inform the users of what they need to do to interact with the virtual environment, we considered two different options. One was to have directions presented at the beginning of each interaction and the other was to have most of the interactions be based on one button and then subtly guide the user using visual cues. We decided to go with the latter option as the former would cause the environment to feel too congested between the typography needed to explain the directions and typography for the statistics regarding coral reefs. The visual cues we decided to utilize were different particle systems from the Unity Library. A particle system would run to highlight the possible objects/corals that the user can interact with (see Figure 6). Once the user interacts with the object/corals, the particle system would stop and the next one would start to highlight the next object. When the program starts, the user is presented with the main buttons

in the project description and is told to follow the particle systems. The only section where the user would not use the main button is during the replanting stage where they instead use the down, right, and left arrow keys on the CAVE2 wand to select the desired particle system [9]. Unlike the previous sections, the particle systems highlighted a space on the coral floor versus a physical object. When selected, this particle system would be replaced with the replanted baby coral. This switch from having one main button to three different buttons for this scene was done because testing indicated that using the main button like the earlier interactions would lead to more user error because there was no physical object to point the wand at, so the chances of the user missing the collision point increased.

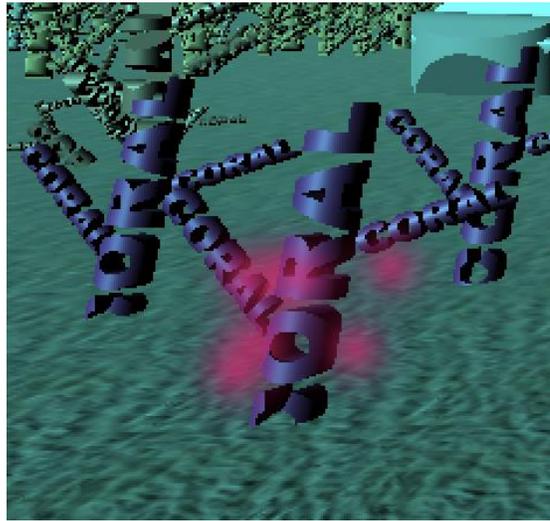


Figure 6: Particle System Highlight

4 CONCLUSION

Through this project's development, our team learned about the urgent situation facing the coral reefs and life below water. The final version of the project was showcased in CAVE2 in EVL/UIC with 50 audience visitors providing feedback and comments about project design and exhibition. Even though we may not have constant interactions with life below water, it is still our responsibility to aid the marine life, including coral reefs, to have a safe and healthy environment to thrive in. There are small things that we can do to help, such as avoiding the pollutants from entering the underwater environment, to bigger things such as utilizing coral nurseries and continuing research on them. We used new tools to represent the importance of this problem and the possible solutions. Our team members had no experience using Unity at the beginning of the process and were able to build a complex scene with interactions by the end of the semester. We also learned how coding and design can work together to create a meaningful experience for users.

REFERENCES

- [1] United Nations. 2022. The Sustainable Development Goals Report 2022. (July 2022). Retrieved April 17, 2023 from <https://unstats.un.org/sdgs/report/2022/>
- [2] Marjo Kristine Vierros. 2021. Assessment of the Impacts of the United Nations Ocean Conference Voluntary Commitments. (2021). Retrieved April 17, 2023 from <https://sdgs.un.org/sites/default/files/2022-01/DESA-Oceans-VCs.pdf>.
- [3] Shedd Aquarium. 2021. Seven Surprising Facts about Coral. (November 2021). Retrieved April 17, 2023 from <https://www.sheddaquarium.org/stories/seven-surprising-facts-about-coral>.
- [4] Pacific Coastal and Marine Science Center. 2022. Coral Reef Facts. (June 2022). Retrieved April 17, 2023 from

<https://www.usgs.gov/centers/pcmsc/coral-reef-facts>.

- [5] Environmental Protection Agency. 2022. Basic Information about Coral Reefs. (June 2022). Retrieved April 17, 2023 from <https://www.epa.gov/coral-reefs/basic-information-about-coral-reefs#:~:text=Coral%20reefs%20provide%20habitat%20for.and%20many%20species%20of%20fish>.
- [6] The Atlantic. 2016. A Breakthrough for Coral Reef Restoration. Video. Retrieved April 17, 2023 from <https://youtu.be/qHKpcnn5Tws>.
- [7] NOAA Office of Habitat Conservation. 2021. Restoring Coral Reefs. (September 2021). Retrieved April 17, 2023 from <https://www.fisheries.noaa.gov/national/habitat-conservation/restoring-coral-reefs#how-we-restore-coral-reefs>.
- [8] Global Coral Reef Alliance. 2009. Biorock™, Mineral Accretion Technology™, Seament™. (2009). Retrieved April 17, 2023 from <https://www.globalcoral.org/biorock-coral-reef-marine-habitat-restoration/>.
- [9] Febretti, A., Nishimoto, A., Thigpen, T., Talandis, J., Long, L., Pirtle, J. D., ... & Leigh, J. (2013, March). CAVE2: a hybrid reality environment for immersive simulation and information analysis. In *The Engineering Reality of Virtual Reality 2013* (Vol. 8649, pp. 9-20). SPIE.
- [10] National Geographic. 2020. Journey into the Deep Sea - VR | National Geographic. (July 2020). Retrieved May 1, 2023 from <https://www.youtube.com/watch?v=EbUHKw8r5xA>.
- [11] Centre for Sea and Society. (September 2022). Virtual Reality helps people meet the ocean. Retrieved May 1, 2023 from <https://www.gu.se/en/news/virtual-reality-helps-people-meet-the-ocean>.
- [12] Delacy, Caine. (2016, July). 360-Degree Video: A New, Exciting Tool for Underwater Research. Retrieved May 1, 2023 from <https://oceanfirsteducation.blue/node/202>.