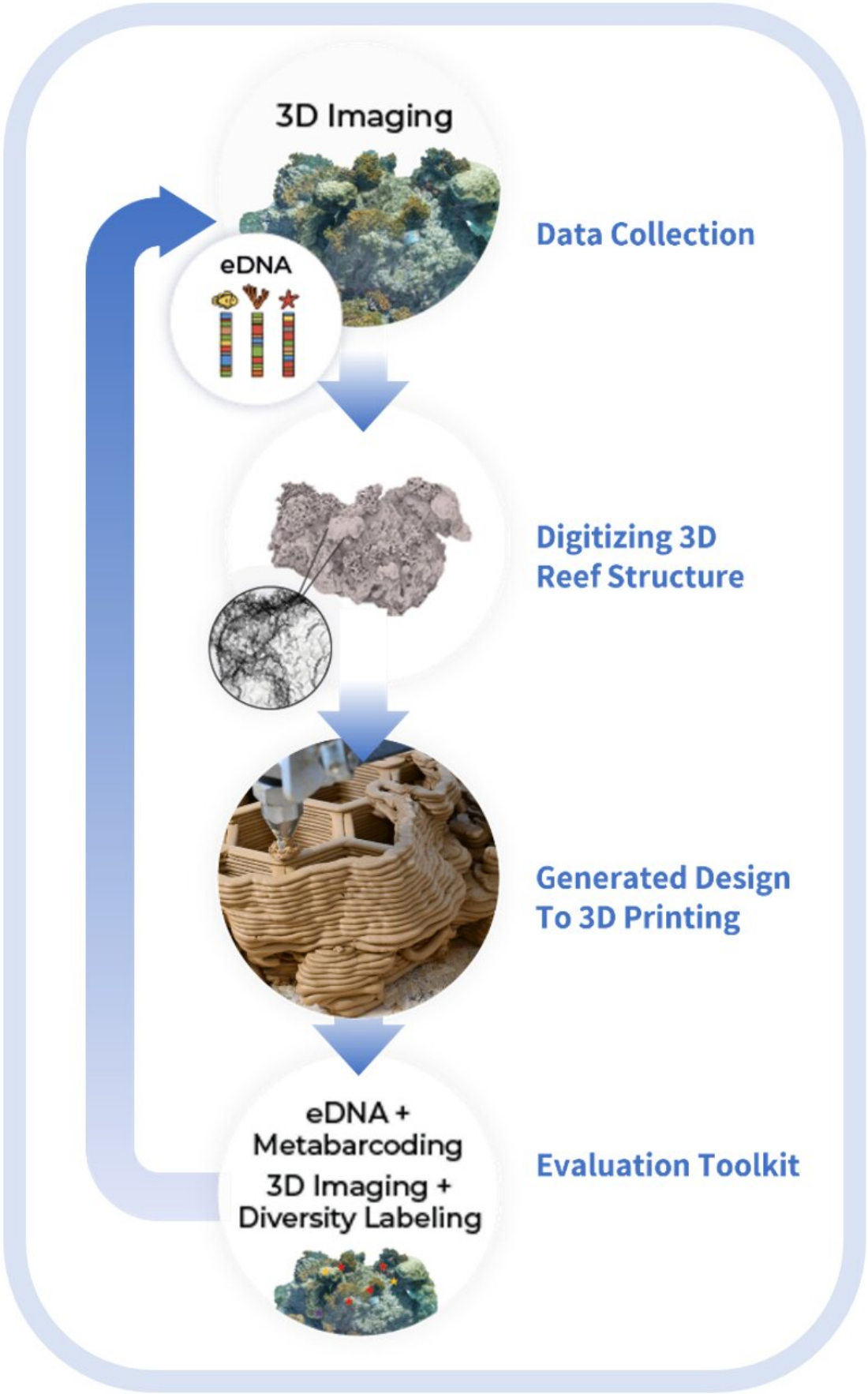
Reforming coral reefs using 3D printing

April 26 2022


3D Imaging
eDNA
Data Collection
Digitizing 3D
Reef Structure
Generated Design
To 3D Printing
eDNA +
Metabarcoding
3D Imaging +
Diversity Labeling
Evaluation Toolkit

The workflow of 3D interface, starting with data collection using molecular tools and 3D imaging. Next, the translation of 3D reef structure based on the reef's biodiversity and core characteristics to generate a design for the 3D printer, followed by the evaluation of the reef reformation goals using the molecular and 3D imaging evaluation toolkit. Credit: Natalie Levy and Ofer Berman

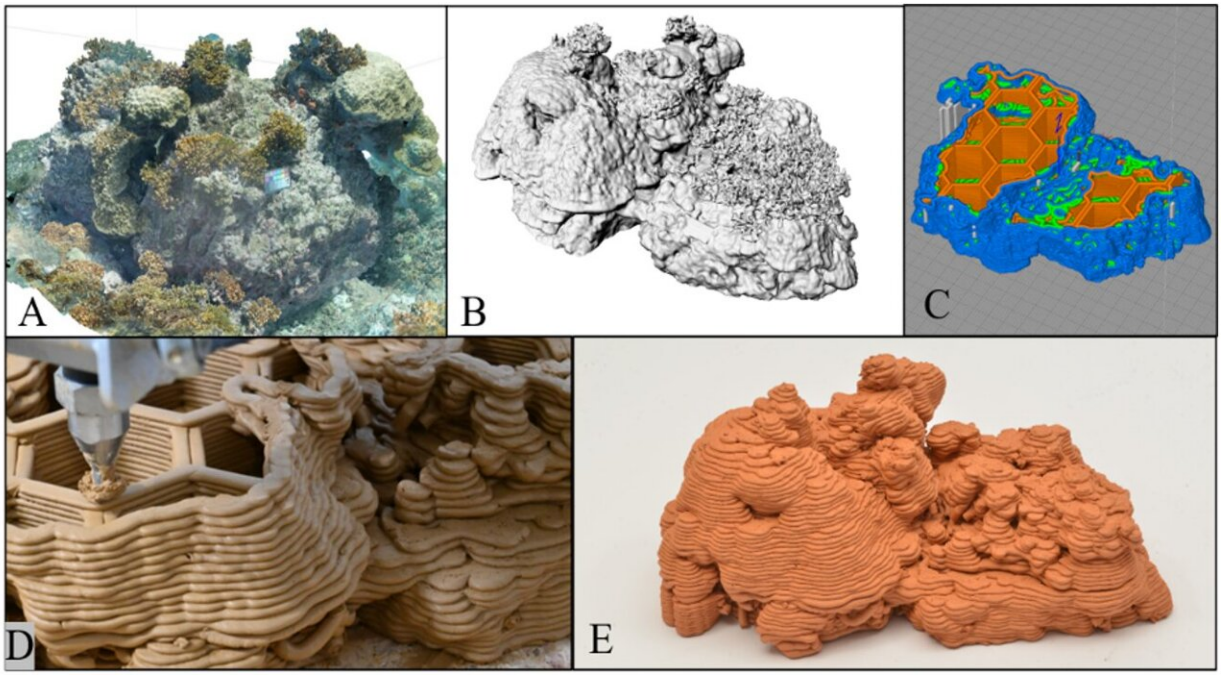
The world's coral reefs are becoming extinct due to many factors such as global warming and accelerated urbanization in coastal areas, which places tremendous stress on marine life. "The rapid decline of coral reefs has increased the need for exploring interdisciplinary methods for reef restoration," explains Natalie Levy, a Ph.D. student at Bar-Ilan University in Israel. "Examining how to conserve the biodiversity of coral reefs is a key issue, but there is also an urgent need to invest in technology that can improve the coral ecosystem and our understanding of the reef environment."

In a paper recently published in the journal *Science of the Total Environment*, researchers from four of Israel's leading universities highlight a 3D printing method they developed to preserve coral reefs. Their innovation is based on the natural structure of coral reefs off the southern coastal Israeli city of Eilat, but their model is adaptable to other marine environments, and may help curb reef devastation plaguing coral ecosystems around the world.

The joint research was led by Prof. Oren Levy and Ph.D. student Natalie Levy, of the Mina and Everard Goodman Faculty of Life Sciences at Bar-Ilan University, Prof. Ezri Tarazi and Ph.D. student Ofer Berman, from the Technion's Architecture and Town Planning Faculty, Prof. Tali Treibitz and Ph.D. student Matan Yuval from the University of Haifa,

and Prof. Yossi Loya of Tel Aviv University.

The 3D process begins by scanning underwater photographs of coral reefs. From this visual information, a three-dimensional model of the reef is assembled with maximum accuracy. Thousands of images are photographed and sent to the laboratory to calculate the complex form of the reef and how that form encourages the evolution of reef species diversity.



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Next, the researchers use a molecular method of collecting

environmental genetic information which provides accurate data on the reef's organisms. This data is incorporated with other parameters and is fed into a 3D technology algorithm, making it possible to build a parametric interactive model of the reef. The three-dimensional model can be designed to precisely fit the designated reef environment.

The final stage is the translation and production of a ceramic reef in 3D printing. The reefs are made of a unique ceramic that is naturally porous underwater and provides the most ideal construction and restoration needs to the affected area, or for the establishment of a new reef structure as a foundation for the continuation of life. "Three-dimensional printing with natural material facilitates the production of highly complex and diverse units that is not possible with the usual means of mold production," says Prof. Ezri. Tarazi.

The process combines 3D scanning algorithms, together with environmental DNA sampling, and a 3D printing algorithm that allows in-depth and accurate examination of the data from each reef as well as tailoring the printed model to a specific reef environment. In addition, data can be re-fed into the algorithm to check the level of effectiveness and efficiency of the design after it has been implemented, based on information collected in the process. "Existing artificial reefs have difficulty replicating the complexity of coral habitats and hosting reef species that mirror natural environments. We introduce a novel customizable 3D interface for producing scalable structures, utilizing real data collected from coral ecosystems," emphasizes Natalie Levy. Ofer Berman adds, "The use of three-dimensional printing allows extensive freedom of action in reality algorithm-based solutions, and the assimilation of sustainable production for the development of large-scale marine rehabilitation."

This study meets two critical needs to save coral reefs, according to the researchers. The first is the need for innovative solutions that facilitate

large-scale restoration that can be adapted to support coral reefs worldwide. The second is the recreation of the natural complexity of the coral reef—both in size and design—that will attract reef species such as corals, fish, and invertebrates that support the regrowth of natural coral reefs. The researchers are currently installing several 3D printed reefs in the Gulf of Eilat. They believe that the results they obtain will help them apply this innovation to other reef ecosystems around the world.

More information: Natalie Levy et al, Emerging 3D technologies for future reformation of coral reefs: Enhancing biodiversity using biomimetic structures based on designs by nature, *Science of The Total Environment* (2022). DOI: 10.1016/j.scitotenv.2022.154749

Provided by Bar-Ilan University