Reimaging Coral Reefs: Remodelling Biological Data in the Design Process

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Abstract

Coral Reefs are filled with infinite and unique forms, variations of shape, and complex phenomena and processes. These forms and processes have inspired both scientists to document, archive and collate, and designers to reimagine these intricate ecosystems in their creative design work. In this paper, we explore how designers integrate scientific data from coral reefs, by examining two projects. Firstly, we discuss *Reefs on the Edge,* an interactive installation using scientific data from a marine biologist to visualize the effects of ocean warming on corals reef ecosystems. Secondly, we discuss *Coral Colonies,* an installation that adapts mathematical codes of coral geometries to create biomimetic coral prototypes. We conclude how design and science use visual data taken from biological processes to help raise awareness and promote biodiversity, sustainability and the survival of the Great Barrier Reef (GBR).

Keywords

Coral Reefs, Code, Interaction Design, Drones, Tangible User Interface Design, Interactive Installation, Climate Change, Marine Biology, Transdisciplinary Collaboration

Introduction

While scientists use data and biological processes to observe, measure, analyse and categorise, designers explore biological data to create, shape and design materials. Biology as a discipline of science seeks principles of order by researching phenomena of the natural world through, observation, measurement, analysis, and categorisation; this raw material may be deployed as an instruction manual in a design context (Reinhardt, 2015).

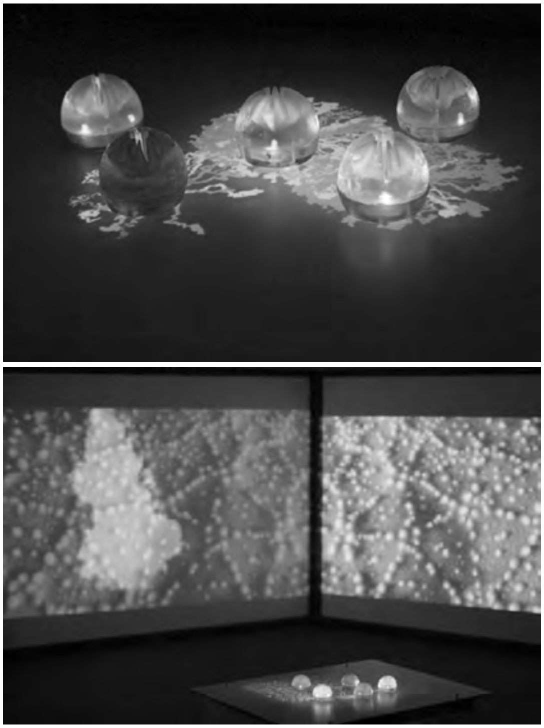
Generic systems as found in nature, universal biological methods and principles, biomimicry and biomimetics have increasingly become drivers and problem solvers in diverse fields - from science to design. In nature, unique variations develop through universal code according to specific affordances. The same principles can be found in the way structures and organisations are formed, and information is processed.

In this paper, we show how biological processes taken from coral reef ecosystems have become an inspirational site of exploration for designers to reimagine scientific data in interactive installations. We discuss how two research installations - *Reefs on the Edge* and *Coral Colony* - integrate biological data into the design process to reimagine, and potentially reconfigure, coral reefs.

Background

The Great Barrier Reef (GBR), the world's largest coral reef ecosystem, is situated in northern Australia and covers over 344,400 kms. It includes over 3000 coral reefs, 600 continental islands, and approximately 150 inshore mangrove islands (DSEWPC 2013). Twenty-five percent of biological organisms populate these beautiful complex forms. Yet despite being one of the most astonishing places on Earth, more than one quarter of coral reefs in the GBR have recently disappeared due to widespread coral bleaching (Hughes et al. 2002). The effects of climate change, such as ocean acidification, ocean warming, pollution, overfishing, and sea level rise, threaten coral reef ecosystems. Higher ocean temperatures have been shown to cause coral bleaching (Hughes, 2003; Hoegh-Guldberg et al. 2007; Pandolfi et al. 2011). Multiple and diverse data are currently being collated that document the condition of the reef.

In order to combat conditions caused by climate change in the GBR, urgent transdisciplinary collaboration in fields such as biology, design and architecture are necessary. These transdisciplinary collaborations can provide design solutions to regenerate coral reefs. In this paper, we explore how the creative interpretation of biological data through processing and scripting methods can be applied for interactive design installations; consecutively educate audiences about coral reef ecosystems; and foster desire to preserve these intricate ecosystems. These creative works act as boundary objects between the different disciplines that range from marine science to biology to computational design, bridging between the different disciplinary criteria, concepts and frameworks (Star and Griesemer 1989).



1. (Top) Reefs on the Edge, Tangible User Interface Objects; simulating Coral Bleaching. (Bottom) Multiple Channel Video, and Tangible User Interface Table ©Caitilin de Bérigny

Reefs on the Edge

In this section, we discuss *Reefs on the Edge* (2011-2016), an interactive installation created using scientific data collected by marine biologist Dr Erika Woolsey. Woolsey's research investigated the survival of young corals in the Great Barrier Reef, and the effects of temperature on embryonic development (Woosley, 2013). The impetus to create *Reefs on the Edge* was to visualize Woolsey's scientific data, and to educate audiences about climate change in the GBR.

Reefs on the Edge gives audiences an opportunity to learn about rising sea temperature, and the effects on coral reef ecosystems. The data is visualised by abstractly representing coral bleaching (figure 1 top), and spawning (figure 2). Depending on how long the audience engages with the object, the simulation either 'spawns' or 'bleaches'.

Reefs on the Edge was designed by Caitilin de Bérigny and created by a team of researchers at Sydney University. Designers Phillip Gough and Adityo Pratomo built the TUI objects; Ge Wu edited the multiple -channel video installation; and Michael Bates created the soundscape.

Figure 2. Reefs on the Edge, Interactive Installation. Tangible User Interface Table ©Philip Gough

Data Visualization-Reefs on the Edge

Reefs on the Edge is comprised of a tangible user interface (TUI) table (figure 1 top and figure 2), and a three-channel video installation (figure 1 bottom). For the previous, the scientific data collected by Woolsey was integrated into a four-dimensional installation, by using Processing to create the data visualization which controlled a video-projection onto TUI tables:

"Processing has been used for a broad range of purposes—from artistic to analytical— to communicate data and is an ideal platform for interactive installations, such as *Reefs on the Edge*, to enhance the artistic and scientific display digitally and help users relate to information" (de Bérigny et al. 2014).

The data was communicated to and explored by an audience when they manipulated the TUI objects on the table. By moving the TUI objects, shifts in the processing sequence were inducted and data flows immediately simulated, so that the audience learnt about impacts of minute and gradual but irreversible changes on ecosystems such as raises in sea temperature on coral embroys.

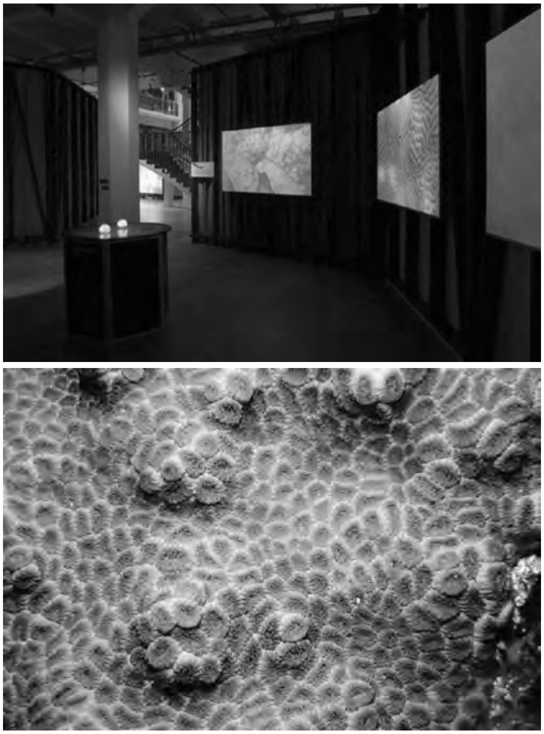


Figure 3. (Top) Reefs on the Edge. Exo-Evolution, GLOBAL, ZKM at the Center for Art and Media in Germany (2015 to 2016), ©ZKM. (Bottom) Image of Coral, taken by Charlie Veron, used in the film Reefs on the Edge (2002) ©Charlie Veron

Communicating Data: Video Installation

Surrounding the exhibition is a multiple three-channel video installation (see figure 3). Like the TUI table, the communication of the scientific data was translated into the video component. The aspiration behind the video was to visually translate the effects of ocean acidification, raises in ocean temperature, and pollution in a non-didactic, visually engaging manner.

The installation employs current visual imagery, taken by de Bérigny on a field trip to One Tree Island Reef (see figure 4 bottom), comprises underwater photographs. The sound was recorded from an underwater microphone, designed and edited into a musical composition by Michael Bates. Significant visual data were further donated by former Chief Marine Scientist of the *Institute of Marine Science* (see figure 4).

Charlie Veron, known as the 'Godfather of Coral', discovered over 20% of all coral species globally. He collected photographic documentation of the major coral reef regions, participating in 66 expeditions, spending 7,000 hours scuba diving (Veron 2002; Veron & Stafford-Smith, 2000; Veron 1986).

Figure 4. Image of Coral, One Tree Island Reef (2014) © Caitilin de Bérigny

Veron's scientific data (see figure 4) was further juxtaposed with artistic images of coloured dye. Dye is used here as a visual metaphor; representing acidification, pollution and changes in sea temperature (see figure 3). The dye sequences were layered on black and white images of coral; alluding to coral bleaching.

The interactive installation *Reefs on the Edge* developed through various design iterations, and was shown in numerous exhibitions: including the *Exo-Evolution* (figure 3) at ZKM The Center for Art and Media in Germany (2015- 2016), and in the *Meaning* *of Life: Celebrating 50 years of Biological Sciences* at Macleay Museum (2013-2014). The work featured in an exhibition at Web Directions and was shown in an exhibition; Attract: Relate: Sustain, at the Verge Gallery in Australia.

Reefs on the Edge is a transdisciplinary collaboration in biology, design, art and acoustics, leading to an interactive installation that employed scientific data in the design process. Through the close- up and tangible display of slow but fatal effects on embryonic corals precipitated by ocean warming, the work communicated the effects of climate change on the reef, thus providing a space to learn about the GBR in an engaging, interactive environment through multi-modal interaction (sight, sound, touch).

Several aspects are key in the two installations that are discussed here; the visualisation, the embodied knowledge, and the human/non-human relations. We argue that biological processes, taken from coral reef ecosystems, can become an inspirational site of exploration for designers to reimagine scientific data in interactive installations. In this shift, observation, rationality, and economy take on different forms, beyond mere data management and analysis. By employing what Halpern coined 'communicative objectivity', attention and empathy of the audience is drawn to micro-conditions that have global impacts, and so, transformations in governmentality can be potentially initiated (Halpern 2015). In a similar manner, data is employed in *Coral | Colony*.

Figure 5. Coral |Colony, Future Nature exhibition, Australian Design Center, Sydney (2015) ©Dagmar Reinhardt

Data Visualisation- *Coral |Colony* (2015)

Coral | Colony collates research investigations into natural morphologies and systems, developed by Dagmar Reinhardt (2010-15) and exhibited as part of "Future Nature" (Australian Design Museum, 2015). *Coral | Colony* comprises a range of media: marine specimens found in the inter-tidal zones of Australian Eastern beaches (New South Wales and Victoria); video clips of scientific documentations; animations of 3D-modelling processes, and segments of code. This archive uses different data sets; (found) natural specimen; and (man-made) boundary objects, to communicate nature in a tactile, and visually engaging manner (figure 5).

Coral | Colony explores multiple heterogeneous systems where an organism formed of singularities (the coral) contributes to form a larger ecosystem (the colony). The term "colony" describes the correlation and interchanges between numerous life forms. The colony's core and most predominant component - the *coral reef* - is a non-finite structure, with dynamic behavior and growth patterns. It is a multi-dimensional entity comprised of opposites; the animate and inanimate; the mobile and stationary; the temporal and generational systems that continuously evolve. The colony changes in a choreography with other entities (corals, fishes, plankton, etc.), and adapts by actuating an inscribed mathematical, and evolutionary code.

Data (Re)Design: Code to Fabrication

Corals are highly complex organisms that illustrate visible continuous changes, and unique variations. The biomimetic design approach for this work, applied mathematical logic in generative systems to create diverse forms and morphological variations.

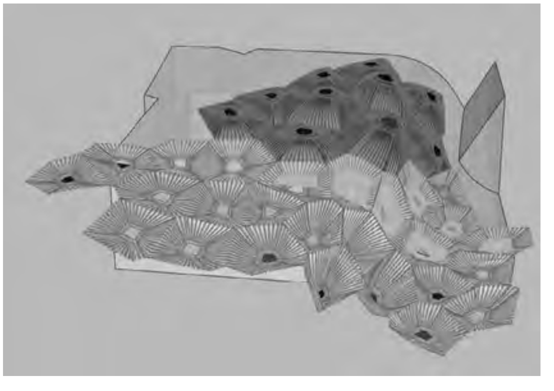


Figure 6. InteractiveCorals: Voronoi coral modules on reef segment (2015) ©Dagmar Reinhardt, EndOfLine

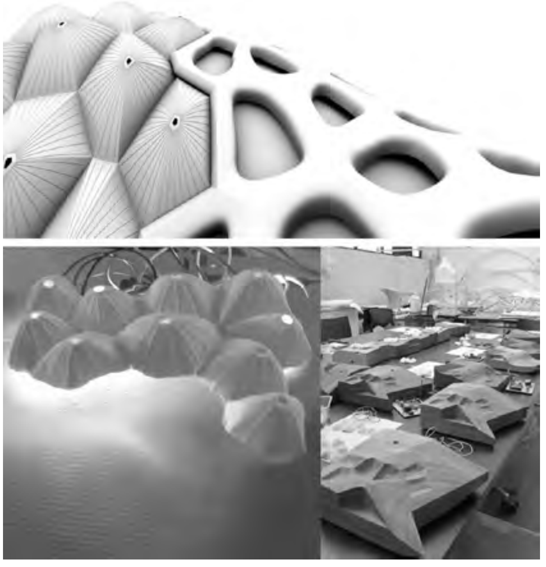


Figure 7. InteractiveCorals: Geometry Data Visualisation, Interactive LED, Modules (2015) ©Dagmar Reinhardt, EndOfLine

InteractiveCorals created a segment display of coral reef structure, with twelve modular components that contribute to the larger complex ecosystem. Modules consisted of multiple materials (mahogany, porcelain, LEDs). Audience members that engaged with the modules on a tactile level, experienced a pulsing of the corals light emission that mirrors their heartbeat frequency (figure 8). The *pulse of life coral sculptures* embodies these principles, in their formation and as a metaphor for relational structures and networks.

Several different steps of prototyping, material computation, coding and digital manufacturing translated the mathematical code for the coral pieces; from a) the organization of principle geometries in 3D modeling and scripting processes; to b) dataset transfer in digital and analogue manufacturing (CNC and Rapid Prototyping, slip-casting processes, and firing stages); and finally to the c) pathways of prototyping and finalizing live entities with pulse sensor and lighting patterns.

Examples of code found in deep sea corals used here included Voronoi geometries in cellular coral growth, turing patterns, or branching structures based on L-systems. These rules are mathematical instructions; code, or DNA sequences that are applicable in dynamic systems. This code is a complex data set, developing through time.

In the first step, the geometry was modelled in parametric and scripting software (3D-modelling McNeel Rhino, plus Grasshopper plugin). In these isolated areas, two Voronoi pattern codes for a coral population are associated with individual base modules (figure 6). These two Voronoi populations of coral growth differ in geometry, are situated on the local topography, and inhabit density and expansion of each module's surface plane (figure 7). Singular cells of the Voronoi corals respond this surface as 'lost population'; they are engraved as negatives or 'ghosts' on the surface, thus echoing the 'live' and glowing corals (Figure 8).

The scripting sequence mimics the biological data through geometry. Both coral populations share similar appearances that organize relationships between individuals in the group (the Voronoi). The two species of corals exemplify different evolutionary lines, identified through 'profiling' of their structural skeleton and dimensions by touch.

In the second step, a transfer of dataset to digital manufacturing and fabrication was used to constitute the computational prototype. Two base sets were digitally fabricated for production in EPSF Styrofoam (for mould-making, and slip casting porcelain process), and a CNC routed mahogany base. 3D modelling files were reworked according to machine toolpath, and data send as fabrication command to rough and fine routing of module formwork, and for routing the engraved sequences of corals.

The fabrication then employed a slip casting process (Styrofoam to plaster to slip cast), where the original geometry was reproduced from the routed form, in a first plaster formwork; as singular cast; and the fired, cooled, glazed and refired, bridging between the universal coding, and the material constraints (figure 8).

Finally, and as a last transfer of data and code, the human pulse is conceptualized as giving life to the coral entities. A pulse sensor is embedded in the wooden base. A soft glow is emitted by LEDs underneath the coral structures. When a pulse is detected, the lone red LED blinks and a lighting pattern plays on the blue LEDs, before reverting back to the soft steady glow.

Figure 8. InteractiveCorals: (Left) prototypes for Voronoi coral modules. (2015) ©Dagmar Reinhardt, (Right) Brain Coral Study (2015) © Dagmar Reinhardt, EndOfLine

In *InteractiveCorals* biological data was used as a biomimicry approach in shape appearance, and the responsive behavior of the coral. The mathematical logic is here used as a multi-level tool; from generative and manufacturing to interaction and experience processes.

Future Trends in Data Collection

Developments in new technologies continue to create new methods to collate, document and visualize biological data. Drone technology provides high quality aerial footage, visualizing changes in coral reef ecosystems. Sydney University video artist Nathaniel Fay, in collaboration with a marine scientist, architect, and designer, currently explores processes for aerial drone data from the GBR, for a slow/change, large/scale research project (2017-2019). This drone footage research will provide new interdisciplinary methods to retrieve and consecutively interpret biological data. Projected outcomes will include systems of data visualisations and new media art installations that engage designers, scientists and audience.

Furthermore, there are currently a number of global initiatives forming transdisciplinary collaborations in design, architecture and biology to develop artificial reefs. One such example, is the *Reef Design Lab*, a multidisciplinary team in biology, engineering and design. In the *Reef Design Lab*, designer Alex Goad created a Modular Artificial Reef System (MARS) (see figure 9). The artificial reef MARS, is comprised of modules; designed to provide diverse benefits to species specific habitat. The dimples on this MARS were designed to facilitate attachment of live coral; which grows to the structure, reshaping it into a living reef.

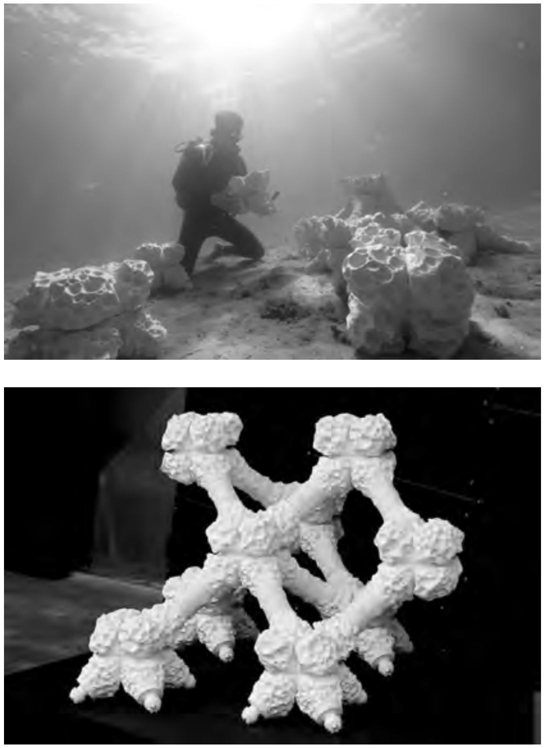


Figure 9. (Top) Modular Artificial Reef System (MARS), designed by Alex Goad. (Bottom) Alex Goad installing MARS underwater. ©Alex Goad

Like the *Reef Design Lab*, in the Maldives, *Reefscapers* developed a coral regeneration project. The project was developed after a massive coral bleaching event in 1998, wiped out over 90% of corals. *Reefscapers* developed by an environmental agency Seamarc, has submerged over 4,000 artificial reefs (Reefscapers 2016). For the project, the team welded dome frames, with a rust proof coating, and attached live coral to the structure. When submerged underwater, corals grow to the structure. Due to widespread global coral bleaching events, the creation of artificial reefs is significant to regenerate coral reefs. This project is an innovative illustration of how design can play an important role in marine conservation.

Conclusion

We explored how designers reconfigure biological data to create, and develop materials in their design process. We examined two interactive installations; *Reefs on the Edge* and *Coral Colony*. Both installations experimentally and creatively integrated biological and scientific data from coral reefs in the design process; through direct implementation of visual imagery, through secondary imagery and metaphorical gestures, through boundary objects and tangible user interfaces, and by using mathematical data to reproduce coral-like objects and tangibles. At the core, these interactive installations explored biological data by creating visualisations through biomimetic design approach in advanced computational code, processing and scripting environments code. Such design-led investigations raise interest in and awareness of the fragility of the Great Barrier Reef; by promoting environmental action to large public audiences in museums and galleries.

The described exhibitions and works are linked with what art-science theory describes as 'the logic of ontology' (Barry 2008), that is, an orientation apparent in diverse interdisciplinary practices towards effecting ontological transformation in and through objects, and as relations between different research disciplines. This is particularly significant with global phenomena which posit challenges such as climate change, which no single discipline can solve.

And while this paper has addressed novel methods for integrating biological data into a design process, much more work and research needs to be undertaken, given the short time frame and urgency of the reef's present condition. Both data collection (such as retrieval via drone's) and advanced fabrication to support coral growth have become more accessible. Most importantly, interdisciplinary collaboration will be the key. Processes such as the ones discussed here can help provide solutions for environmental sustainability for one of the most magnificent ecosystems on Earth; the Great Barrier Reef. In order to sustain biodiversity, and preserve coral reefs, transdisciplinary collaborations in design, biology and architecture are crucial for coral reef regeneration and recovery.

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Author Biography

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Dagmar Reinhardt is the BArchEnvsProgram Director at the Faculty of Architecture, the University of Sydney, and the Master of Digital Architecture Studio Leader. Her Mathematical Code to Relational Networks 363 research is concerned with an interdisciplinary nexus between computational design, structural engineering, acoustics, biology, and architectural design. She has published on design models for latent material formations in fashion and architecture; design thinking for collaborations between engineers and architects; and processes for robotic fabrication of acoustically effective micro and macro geometries. In spatial installations, Reinhardt extends design research towards experiential environments for bodies in space and time. Her work with practice reinhardtjung | architecture and design has been widely published and has received international recognition and numerous awards, and can be found at www.reinhardtjung.de.

Nathaniel Fay is a Master of Philosophy research student in Design at the University of Sydney's Design Lab. His research examines new mapping technologies to collect marine data using drone technology in the Great Barrier Reef. He is the Managing Director of One Ski Digital and works as a videographer and Lecturer in the Design Lab at the University of Sydney. His video work has been published widely and can be found at www.oneskidigital.com.