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Method& Critique *Frictions and Shifts in RTD*

Mineral Accretion Factory: An Underwater Production Process with a Positive Impact on the Environment

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Abstract: Mineral Accretion Factory is an alternative production system of objects and furniture based on the artificial reef production process developed by architect Wolf Hilbertz (Symbiotic Process Laboratory) and biologist Thomas J. Goreau to restore coral reefs and seabed (fauna, flora).
This project is a reflection on an alterproduction from poor materials, primary technical devices, in relation to the economic and environmental context.
Mineral Accretion Factory consists of the immersion of a steel structure (the object's skeleton) connected to a low-voltage supply (solar panel or windmill).
A redox reaction starts, the object is self-generated, made of a material created from the ocean's minerals.
M.AF. demonstrates that a different ways are possible for production:
- integrated within a natural setting (no factory)
- using a basic apparatus and high scientific knowledge (low-tech + high-tech = wild-tech)
- respecting biological production cycles (slow-tech)
- effortlessly and costlessly

This research program through design gives rise to the possibility of setting up production processes that have a positive impact on the environment.
It participates in the emergence of wildtech as defined by the French anthropologist Yann-Philippe Tastevin.
The project started in 2012 in Indonesia on Gili Trawangan island. Today, it continues on La Réunion island with the school of art in a research center on turtles.

Keywords: slow design; coral; artificial reef; Biorock; alter-production

What progress can be seen in shaving off a few hundredths of a second in the manufacturing of a complex plastic part of a consumer product? The production logics at work have found their limits. The role of the designers is also to work to avoid adding an additional object to the World, to advocate a reasonable way not to produce[1] or to advise to produce otherwise according to efficiency criterias that exceed the logic of short-term profit.

A whole section of design practice stands out from industry, which at the same time revives its political sense. Design is a practical investment in our environment: this practice is not just the preliminary "phase" of a process, but it is distributed through all those who interact with objects. But how can we participate in the heterogenization and diversification of the production methods we need? Questioning the forms given to our material environment and by extension its way of doing things, the designers must broaden his field of understanding by experimenting with all kinds of manufacturing devices, from the most alternative and singular to the most common. From self-production (the establishment of a diffuse design supported by all) to all modes of production that are deployed from below thanks to the networking of knowledge and know-how, and from above supported by the quantity of production.

The economy of gesture and means, with the smallest intervention and the least means possible, minimizing therefore designer's actions and a surplus of material just like recycling and reusing policies, if they are a necessity, are no longer sufficient. One possibility to consider would be to work on the inscription of projects in a continuity, in time, so that they could be experienced *in situ*. Taking the time to consider the development of the project, from its conception to its manufacturing as being just as important, if not more important, than the result (a manufactured and decontextualised object). This time, which we have striven to shorten, to make disappear, to decimate, this combined time of thinking and doing can be invested collectively and constitute social and economic added value. Development is also the result of the project. Consideration should be given to measuring the effectiveness of a project on criterias other than optimizing its physical production.

It is not only a logic of technology appropriation, reduced to its simplest expression that we call *low-tech* (which does not mean a denial of technological progress but rather a wiser use), but is accompanied by a specific temporal dimension allowing us to be more in sync with a rhythm of organic production of forms and matter that we could call *slow tech*. Lets consider autogenesis[2]. It is originally an "old doctrine" according to which forms of life can appear *de novo*, without any kind of origin. It is a concept still used in biology. In this context, it is a genesis that occurs under the organism's own impulse, without external influences. Approached from a production perspective, autogenesis is a utopia. The one of a material that is self-generating, self-organizing. The dream of an object that would totally self-produce. A self-production where human intervention would be reduced to a minimum. With the smallest possible impulse the material would blend in quietly, peacefully. This *slow tech* composition process, which goes beyond *low-tech*, tends towards a utopia of *no tech*.

If these issues seem to be purely utopian, I work, in a much more modest way with singular operational capacities that have the merit of going down this path. As a beginning, a crossing of paths, of which, within the limits of its potential, material specificities and by going against the current of most of the industrial logics at work, I have been developing for the past eight years a project for the production of objects by mineral accretion by diverting from its main use an artificial reef system called Biorock.

1 / For example, the project to beautify Place Léon Aucoc in Bordeaux (France) by the architects Lacaton and Vassal. The architects agreed that it was inappropriate to undertake a beautification project for a place where "quality, charm and life exist" and make it an "already beautiful" place. Only simple and immediate maintenance work has been undertaken.

2 / Article written by David Enon for the book "Les 101 mots du matériau dans le design" under the direction of Daniel Kula, Archibooks - Paris 2014.

Artificial reef as a new production plant

The worrying disappearance of corals

Corals, small animals of the cnidaria family, live in colonies, mainly in warm seas. They have the property of making their exoskeleton, calcareous and hard, and thus forming reefs. Coral reefs occupy barely 0.1% of the ocean surface (or 1.2% of the continental shelves), and are home to exceptional biodiversity with essential ecological functions. They offer an unparalleled panorama of underwater life: corals, fish, rays, rays, turtles, sharks, more than 25% of the world's marine biodiversity evolves there; many species depend on it. Coral reefs play a very important role in the absorption of CO_2. While it is customary to say that the Amazonian forest is the lung of the earth, the ocean is the largest carbon sink. The ocean absorbs carbon from the atmosphere and contributes to the reduction of CO_2 levels; nearly 50% of CO_2 absorption is absorbed via plankton, fish and corals. Coral reefs generally form lagoons that act as buffer zones between the open sea and the coast, they protect from wave erosion when it is not a hurricane. A whole part of the coastal and island population depends directly on reefs. Most of the food production and income from fishing and seaside tourism comes from it. Corals, a very fragile protected species, are extremely sensitive to global warming. If the water temperature increases by 1°C, the coral bleaches, if it increases by 2°C, it dies. Coral is also sensitive to the acidification of ocean waters, a phenomenon that correlates with global warming. In 1998, the increase in *El Niño*[3] amplitude, also related to global warming, had disastrous consequences. Beyond forest fires, heavy rains, floods, tornadoes, snowstorms, etc., hundreds of kilometres of coral reefs have been lost. In March 2016, 93% of the Great Barrier Reef[4] was bleached. Although the sensitivity of corals to global warming is verified, man remains one of the greatest reef destroyers. Some fishing methods such as trawling, cyanide or dynamite decimate reefs. The barriers are also being destroyed to provide boat access to seaside resorts.

Artificial reefs

Artificial reefs have been designed to repair man-made damages. According to Ifremer's[5] definition given in 2000, they refer to "structures voluntarily immersed for the purpose of creating, protecting or restoring a rich and diverse ecosystem. These structures can induce animal responses of attraction, concentration, protection and, in some cases, an increase in the biomass of certain species." The principle is simple: it is enough to observe how the fauna and flora invest a wreck. Artificial reefs are a means of combating the desertification of seabed areas that are overstretched by man or damaged by pollution. They also help to preserve the coastline, limit coastal erosion and minimize sand migration as well as repair damage caused by unscrupulous development. There are different forms of artificial reefs: wrecks (boats, buses, tanks and other bulky vehicles), used tire arrangements, etc. Under the pretext of preserving the seabed and coastline, abuses have been committed. Some interventions even looked like underwater landfills. Only after was the toxicity of some operations revealed. New recommendations have been made: objects used as

Figure 1. Dead corals.

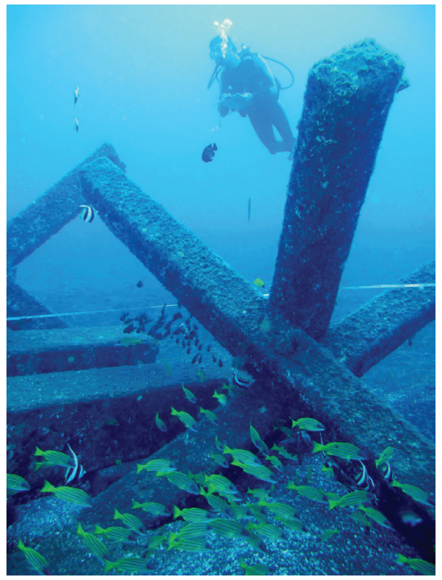


Figure 2. Most artificial reefs are generally made of reinforced concrete. Often existing modules such as nozzles are linked in clusters. Sometimes modules are created for this purpose. In Reunion Island, EDF recycled cement poles have been assembled.

3 / El Niño is originally an ocean current. A unique climatic phenomenon, it results in an abnormal increase in water surface temperature (about 10 meters) in the eastern part of the South Pacific Ocean. It is synonymous with record floods and droughts over a large part of the globe.

4 / The Great Barrier Reef - 2600 kilometers - is located off the coast of Australia and was declared a UNESCO World Heritage Site in 1981.

5 / Institut français de recherche pour l'exploitation de la mer / French Research Institute for the Exploitation of the Sea.

artificial reefs must now be made of inert materials. In France, the artificial reef systems developed are mostly composed of concrete masses, more or less organized and structured. These are often quite cumbersome principles to implement and put in place. The launching of concrete parts requires extensive handling equipment. And if concrete is an inert material, it is nonetheless a foreign material to the marine environment, the quantities of which are colossal here.

Artificial reefs Biorocks

The Biorocks artificial reefs were born from the encounter between Thomas J. Goreau and Wolf Hilbertz. Thomas J. Goreau is a doctor, researcher in biogeochemistry. His research focuses on the impact of climate change, pollution and new diseases on coral reefs in the Caribbean, Indian Ocean and Pacific. His recent work has focused on coral reef restoration, mariculture and coastal protection[6]. Wolf Hilbertz[7] (1938-2007), architect and biologist, has developed numerous prospective architecture projects such as Autopia Ampere [Auto + Utopia + Ampère], which is part of a research project on the concepts of *cybertecture* and *Responsive Environment* that he developed within the *Responsive Environment Laboratory* and the *Symbiotic Process Laboratory*, research laboratories that he founded successively. Even if these architectural projects have never been carried out, they are based on a concrete constructive principle: mineral accretion.

< Figure 3. Biorock artificial reef in Gili Trawangan - Indonesia. Photo: Foued Kadhachi

Mineral accretion is a redox reaction in the marine environment. Redox reactions are common and widely used chemical reactions. They consist of an exchange of electrons between two electrodes (usually metallic) in an aqueous solution. They can be used, for example, to gild metal buttons or key rings. A low voltage current (2 to 6 volts) flows between two electrodes: the cathode and the anode. The cathode is made of a steel structure, usually concrete reinforcement, a low-cost material used all over the world. The anode, on the other hand, consists of a small quantity of titanium mesh, a technical material that is more difficult to find on the market. Once the electrodes are immersed and the current activated, the chemical reaction starts. The calcium carbonate ($CaCO_3$) present in the sea, the same limestone with which coral makes its exoskeleton, is deposited on the cathode. This deposit, obtained by the electrochemical reaction, immediately protects the reinforcing steel from corrosion. Then, slowly, the material agglomerates on the structure and hardens. In three years, with a concrete reinforcement base of about 10 millimeters in diameter, a composite material of 30 to 40 millimeters in diameter is obtained. The structure is then stabilized, it is no longer necessary to supply it with power. Thomas J. Goreau understands that artificial reefs can be built with this device. Lightweight structures, inexpensive and widely available materials, easy installation: it is no longer necessary to throw tons of concrete into the sea. The biologist and the architect define the principles of the Biorock artificial reef system. They are refining the mineral accretion system for a new type of artificial reef. Failing to build underwater habitats for humans, they define the principles of cities for fish, crustaceans, corals, anemones, and any other element of underwater fauna and flora.

6 / His research on the subject is summarized in the book "Innovative Methods of Marine Ecosystem Restoration", Thomas J. Goreau & Robert Kent Trench (dir.), CRC press, 2013.

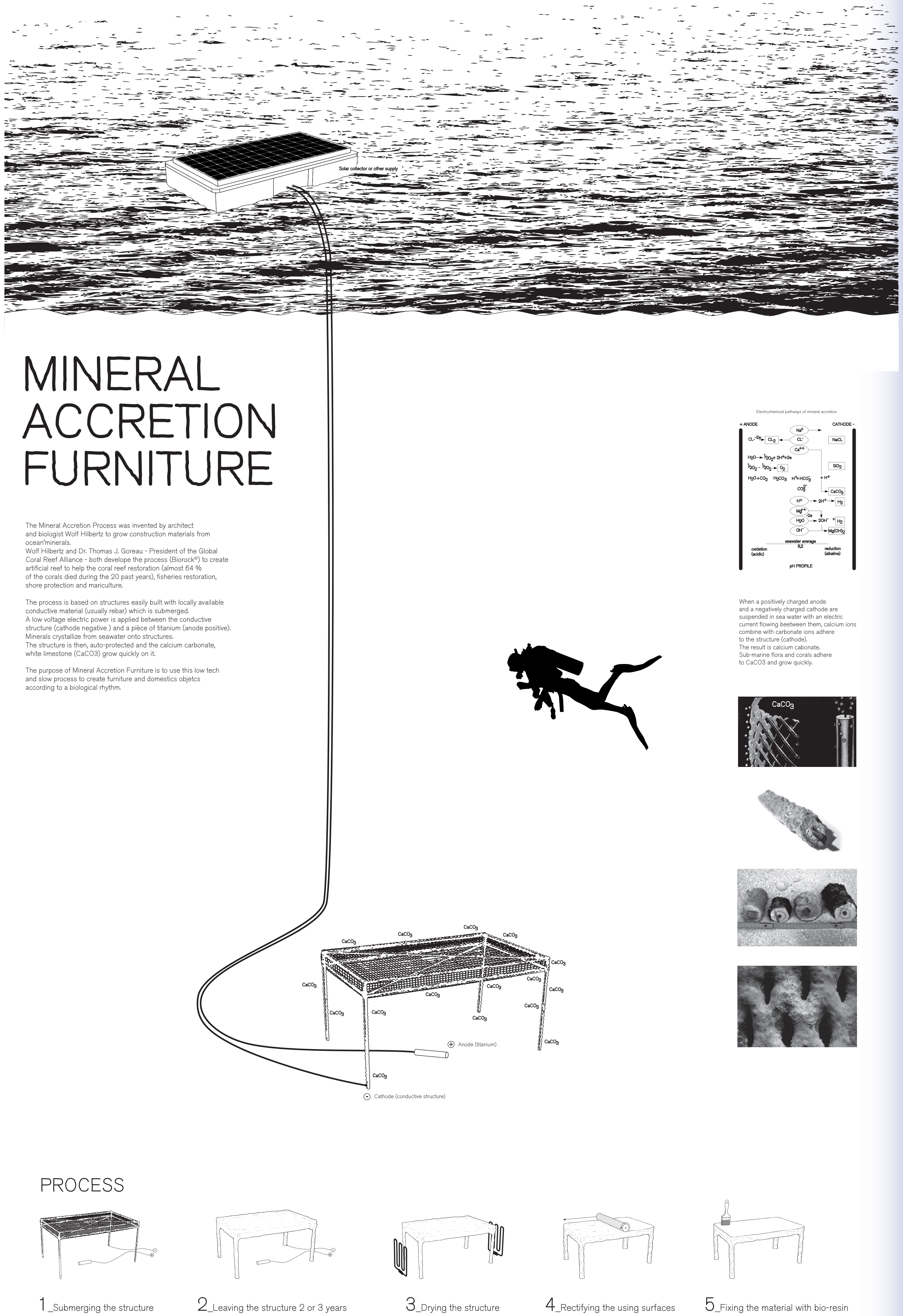
7 / Some of his writings and research are available on the website www.wolfhilbertz.com.

Biorock reefs can be built on a beach invested as a temporary production workshop. All you need is an access to electricity in order to connect a substation for welding. A bolt cutter or a grinder to cut the irons and claws to twist and shape them are enough to build the basic structures of the Biorock reef. These structures do not require any particular precision, and are quickly built. They are fragile and precarious but will be reinforced by accretion. They are lightweight and easy to handle by two or three people. They can easily be hoisted on small boats to be transported to the installation site. The structures are launched with divers or an inflatable buoy system. Divers then go around the natural reefs to collect corals that are detached from the reefs but still alive. They bring them back and attach them with wire on the submerged structures. We're talking about cuttings. The cathode is ready. The anode, made of a few tens of square centimetres of rolled titanium mesh, is placed nearby. The two electrodes are then connected to a low-voltage power source. The current can be drawn from a seaside shop, connected to public lighting or from a generator. Reefs are rarely more than a few tens of meters from the coast and are submerged at a depth of 3 to 10 meters. In the case of installation in an area without an electricity grid, marines buoys equipped with solar panels or wind turbines are used. The connected electrodes trigger the reaction. Hydrogen bubbles form around the structure. They testify the proper functioning of the system. After a few hours, the structure is covered with a film of limestone. Fish invade the reef instantly. Within a few months the structure is generously coated but the added material remains fragile. Corals settle and develop. It takes several months for the limestone deposit to harden and become a resistant material. Initially flexible and fragile, the structure becomes more resistant than reinforced concrete. The low electrical current flowing through the structure concentrates calcium carbonate: it strengthens the reef structure but is also necessary for the construction of the coral exoskeleton and stimulates its growth. Coral growth is five times faster. Observations show that many species of marine flora, such as Posidonia, also develop more rapidly.

Figure 4. Small hydrogen bubbles form around the structure of a Biorock artificial reef under construction. They testify to the proper functioning of the mineral accretion device. Photo: Foued Kadhachi

From Mineral Accretion Furniture to Mineral Accretion Factory

The construction of objects by mineral accretion opens a field of possibilities. By designing fragile skeletons of elements made of iron rods and wire mesh, future furniture can take shape. To do this, it is sufficient to consider the scale and use, anticipate the agglomeration of calcium carbonate and play on the organic and random dimension of the process. To be inspired by the Biorock system in order to produce furniture requires you to think about the whole process: from the drawing of the object to its use after it has been taken out of the



water. Like reefs, we can imagine immersing object's skeletons into a beneficial placement underwater, connecting them and adding coral cuttings to them. Object skeletons can be produced quickly, without any particular requirements. Too fragile and flexible to assume the allocated function, they will become operational thanks to mineral accretion. Two to three years later, the accretion will stop growing. We obtain furniture that is resistant to the constraints of use. The furniture can then be removed from the water. In order to eliminate microorganisms, freeze the object and destroy the marine smell, I imagine exposure to high temperatures (sun, oven...). Minimum finishes would probably be necessary in order to smoothen useful surfaces, such as chair seats or table tops. These finishes should be

< Figure 5. Explanatory poster of the Mineral Accretion Furniture project Illustration : David Enon

< Figure 6. 1/1 scale model of the M.A.F. device for a table before immersion.
(Table skeleton + cable and electrode + floating solar platform)
View of the exhibition "Analog" at the esba TALM, Angers site. Photo: David Enon

< Figure 7. 1/10th scale models of the Mineral Accretion Furniture process prefiguration. Photo: David Enon

as minimal as possible and doable with common power tools. A small and in-situ temporary workshop can be installed for this purpose. It seems essential to me to consider this production according to a rigorous cycle in order to disturb the ecosystem as little as possible. Before removing an object from the water, the corals must be re-implanted on a new virgin structure. We will favor in-situ production, on a small scale, as close as possible to the area where the objects will be used in order to limit the environmental impact as much as possible. The management mode to be implemented should be compared to that of a forest. When a forest is well managed, timber harvesting is negligible for the ecosystem.
It is on the island of Gili Trawangan, as part of the *8th Indonesian Biorock reef restoration training workshop*[8] that I manufactured and implanted the first prototype table and chair in mineral accretion. Located in Indonesia, the island of Gili Trawangan has a perimeter of seven kilometres. Its inhabitants live from fishing and tourism

8 / The obtaining of the support allowance for the development of artistic research from the National Plastic Arts Centre (CNAP) in 2012, allowed participation in the workshop led by Thomas J. Goreau and Delphine Robbe.

organized around diving. The area known as the "golden triangle" in which the island is located is an internationally renowned "spot". It is home to one of the world's largest underwater biodiversity measurements. To preserve it, a dialogue has been initiated between divers and fishermen. On each dive in Gili, five dollars are collected and redistributed to the fishermen's association. In exchange, they must respect a traditional fishing method. In continuity, many ecological initiatives have been put in place, such as a policy to eliminate plastic bags or the installation of septic tanks. Rarely in poor territories, is the ecological question raised, treated and shared in a profitable and concerted investment.
This context proved to be conducive to the development of such a project. This experience has confirmed the project's hypotheses and developed the knowledge necessary to control the manufacturing process of Biorock artificial reefs *in situ*. To this day, the table and chair are still submerged. They could be out of the water. But for the time being, they are still the witnesses of the first phase of the project.

It is on the La Réunion Island that new perspectives are opening up. A research project is underway with the School of Art of La Réunion. The objective is to commit the principle of *Mineral Accretion Furniture* towards the establishment of an operational subsea production unit: *Mineral Accretion Factory.*

The first attempt at tangible production of objects was made in the basins of Kélonia in Saint-Leu. Kélonia is at the same time an aquarium, a museum, and a research center dedicated to marine turtles. It is a privileged place for experimentation. Its seaside basins, whose water is continuously renewed by pumps, offer ideal conditions, worthy of a laboratory designed for this purpose, to launch the first production.

Mineral Acretion Factory is an attempt to set up an alternative system for the production of material objects. The typology of the objects that can be produced is unique and its capacities remain limited. It is especially valid in its participation in the diversification of production methods and forms of our environment. It raises the question of an in situ production whose interest lies particularly in its positive ecological impact. It is a low-tech and slow tech system that respects the biological rhythms and production capacities of the earth. If the factory becomes the sea, there is no local involvement (building to be built, car park, access road, dustbins, heating, air conditioning...). The ground hold here is virtuous since it contributes to the reconstruction of the coral reef and accompanies the development of marine fauna and flora. Most of the production is done during naptime, without the use of personnel. It is an object production method that can be adapted to various scales. It can be used for coastal development by producing elements of street furniture or heavier elements such as dikes. It can also contribute to the development of contemporary craftsmanship that is oriented towards the future rather than the clumsy and mercantile folklorization of outdated traditions. For the designers, this type of device reverses the question of design, which can no longer prevail over utility. The structure derives from a minimal and primitive drawing, a simple skeleton of an object whose final shape depends more on the randomness of the process than on the initial drawing.

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Figure 8. construction of the first M.A.F. prototype in the temporary workshop established on the beach of the island of Gili trawangan - Indonesia
Photos: David Enon

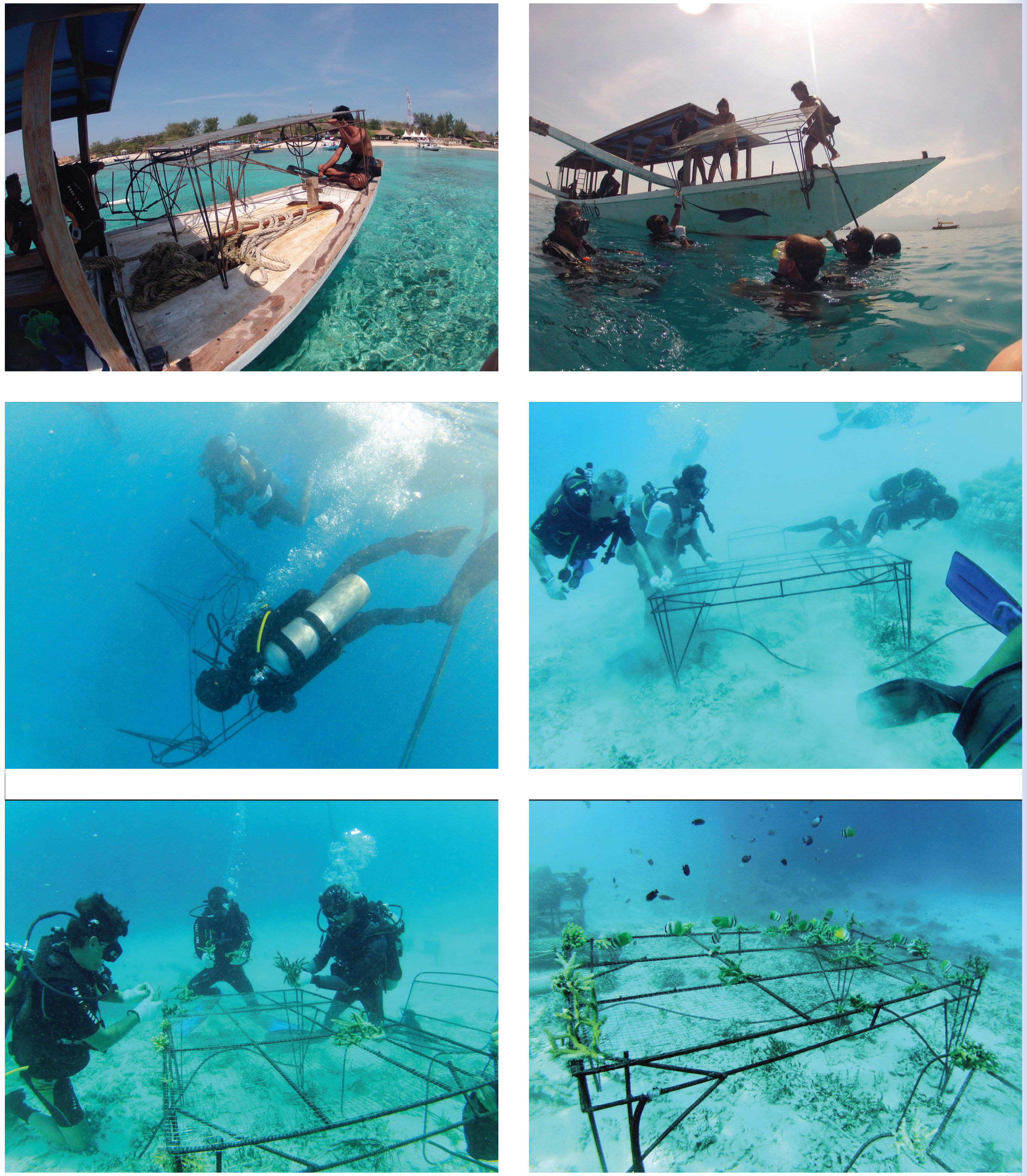

Figure 9. Immersion of the first
M.A.F. prototype off the island
of Gili trawangan - Indonesia.
Photos: David Enon

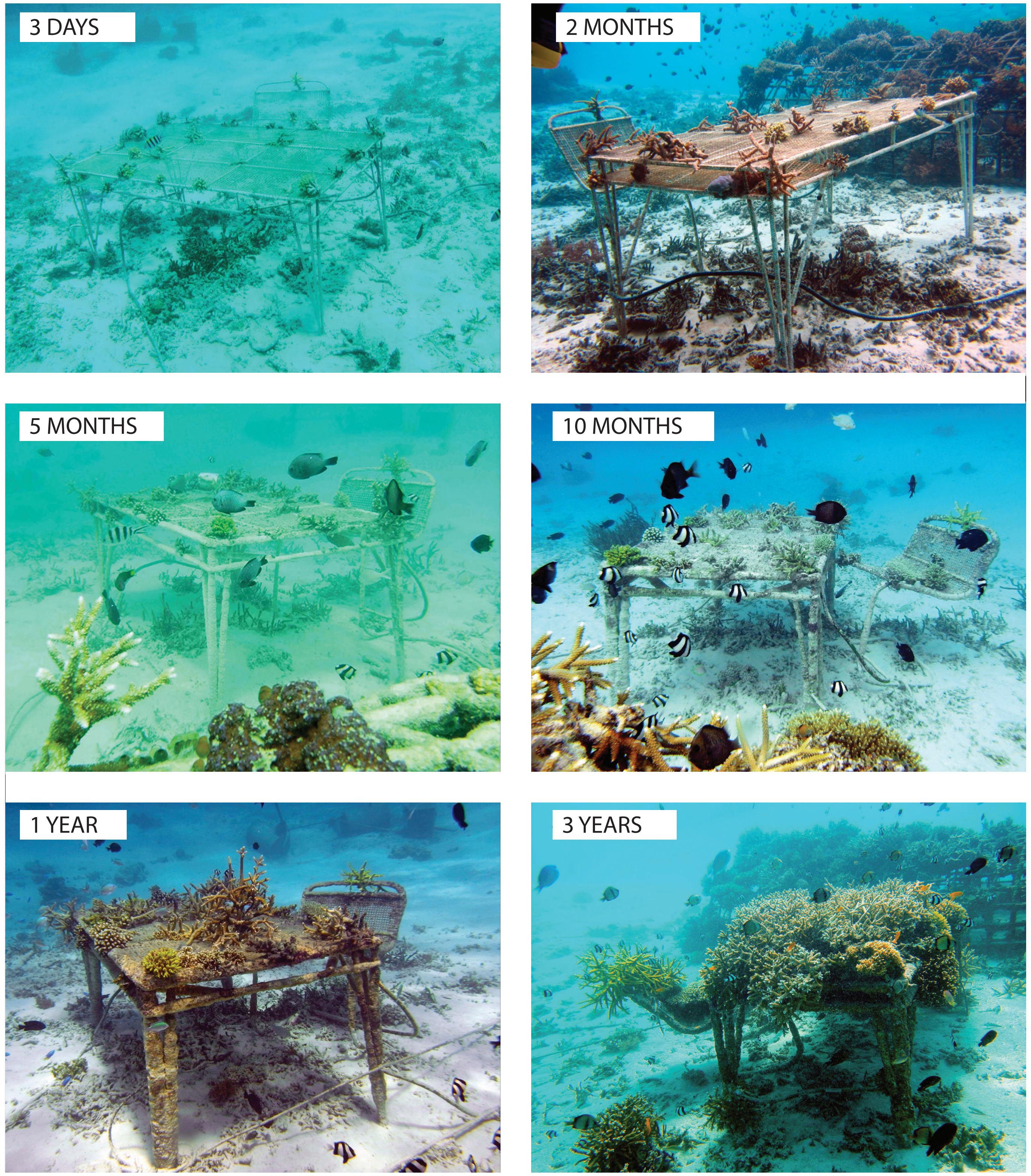

Figure 10. Evolution of the first
M.A.F. prototype off the island
of Gili trawangan - Indonesia.
Photos: David Enon, Foued Kad-
hachi & Delphine Robbe.

Figure 11. mineral accretion test produced in Kelonia (turtle research centre) in La Réunion Island 2017. Photos: David Enon