Dreaming of a digital ocean ...

The Earth, the Blue planet, is so called because its largest biotope is a vast and deep intertwined blue expanse of salted oceans and seas. This liquid is filled with trillions of living organisms that are mostly invisible to the naked eye. These life forms have allowed us to breathe and to conquer terrestrial habitats. They are our ancestors, the rocks we use to build our homes, the oils we use to fuel our society, the food we eat (or the food of our food), and they may also hold the key to a healthy future for our planet in these troubling times of climate change.

Many theories have been proposed, discussed, discarded, and buried about the origin of life; often the ocean is a component of the mysterious mix that gave rise to the chance for life on our planet. Cells first appeared, close to deep sea volcanoes, or perhaps it was in rock pools; in shallow bays, stromatolites trapped sedimentary grains that mark the origin of biological deposits—to which we owe much of the geological nature of the continents—and their cyanobacteria established photosynthesis that made their own food source and released precious oxygen. Life expanded and thrived in these early oceans but there was no one to record the creatures that inhabited them. Nowadays, only the bones and stones left behind provide us a glimpse of the identity of those sea creatures and narrow insights into how they lived. For many millions of years there were no eyes to see them, and no arm and digits to draw them or to build cameras to record this massive world which is up to 12 km deep and which spans 71per cent of our Earth.

Naming and picturing the world around us is the oldest scientific endeavour of mankind. The first witnesses of ocean life drew dolphins on rock faces with bright natural pigments. These are the first known images of an ocean creature painted by men, probably 10,000 years ago, a beautiful first attempt to approach the Great Blue Beyond. Since then, generations of scientists like Aristotle, Guillaume Rondelet and Antoine van Leeuwenhoek opened our eyes through the first microscopes to the magic wonders of the sea, the tiny 'Animalcules', the ever-wandering drifters. Since then the list has been ever growing of those who have made images of ocean life: painting jellyfish (François Péron), engraving radiolarians (Ernst Haeckel), drawing the magical vampire squid (Carl Chun), and in our time recording live animals underwater (Jean Painlevé).

Technological development allows us today to digitally image much smaller organisms (viruses and giruses) collected from the Mariana Trench, the deepest part of the oceans. Cameras provided us with colour imaging and the possibility to create digital recordings of those organisms. Rather than physically capturing an ever-growing number of ocean drifters and other deep-sea creatures during increasing numbers of marine expeditions, we believe that we can take advantage of the digital age to create an interactive 'Deep Blue'. Not the IBM brain simulation project, but a Digital Ocean. Using advanced technologies for imaging and visualization we could digitally follow the ocean currents, observe fish in their full three dimensions, and swim within coral reefs that are being kept safe from unwanted human exposure and

Fig. 3. Portrait of a recently hatched green turtle, *Chelonia mydas*. This species is considered highly endangered. Location: Saint Brandon (Cargados Carajos), Mauritius, Indian Ocean. Image: Aldine Amiel/TARA Oceans/Kahi Kai Images.

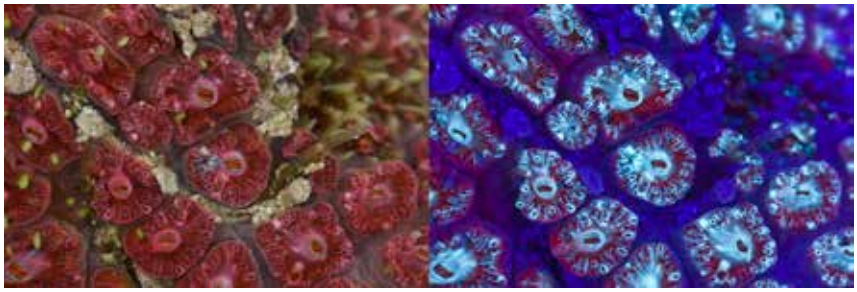

Fig 1. Recording coral fluorescence. An ongoing project involving three dimensional and multispectral analysis of coral communities from reef to symbiont developed in the author's laboratory. Image: Luis Gutierrez-Heredia.

Fig. 2. E. Reynaud on board Tara off Spain after two-and-a-half years sailing around the world. Image: Julien Girardot.

impacts (Figure 1). We could at the touch of a screen receive physical and chemical data registered by an army of sensors and buoys floating worldwide. No need for massive ships thirsty for fuel and other black smokers that grid the ocean daily. Yes, we have a dream, the dream of a Digital Ocean.

But first we have to recognize our own part in this. We sailed on smoking ships; we harvested and killed millions of drifters. We still do, but we wish to set our dream free, and for the past few years we have been trying to work differently. We work with local populations who will directly benefit from a Digital Ocean and need it not just to survive, but to thrive, and we work with non-destructive technologies enabling us to record high quality 3D images of animals, whatever their size, along with their environmental parameters. We foresee communities that are able to gather the data they need, not the data we want, and are able to make sense of the results for their own benefit. Yes, we have a dream, the dream of a Digital Ocean.

Tara Oceans (with *Kahi Kai***)**

We took part in the Tara Oceans Expedition (2009–2012), a unique circumnavigation of the Earth's oceans. Tara is a 35-metre schooner designed to analyse and collect plankton communities as well as coral specimens, to establish a freely available database comprising satellite images, geochemical data, images and genomic sequences, in an attempt to holistically describe these organisms. We designed and maintained The TAra Oceans Marine biology Imaging platform (TA.O.M.I) (Figure 2). This unique expedition was challenging due to the Tara's small size, relative lack of stability and the limited amount of available energy to power the optical instruments. Nonetheless, all the effort put into this project was worthwhile. It was a major success and during the journey we collected hundreds of thousands of images. The results gathered during the Tara Oceans expedition led to many scientific publications. The database to underpin the Digital Ocean is in the process of being assembled sample by sample and laboratory by laboratory. We also shared our experiences and techniques through the publication of a book *Imaging Marine Life: Macrophotography and Microscopy Approaches for Marine Biology* (Reynaud E.G. (ed.), 2013), to help marine researchers worldwide to image their favourite creatures.

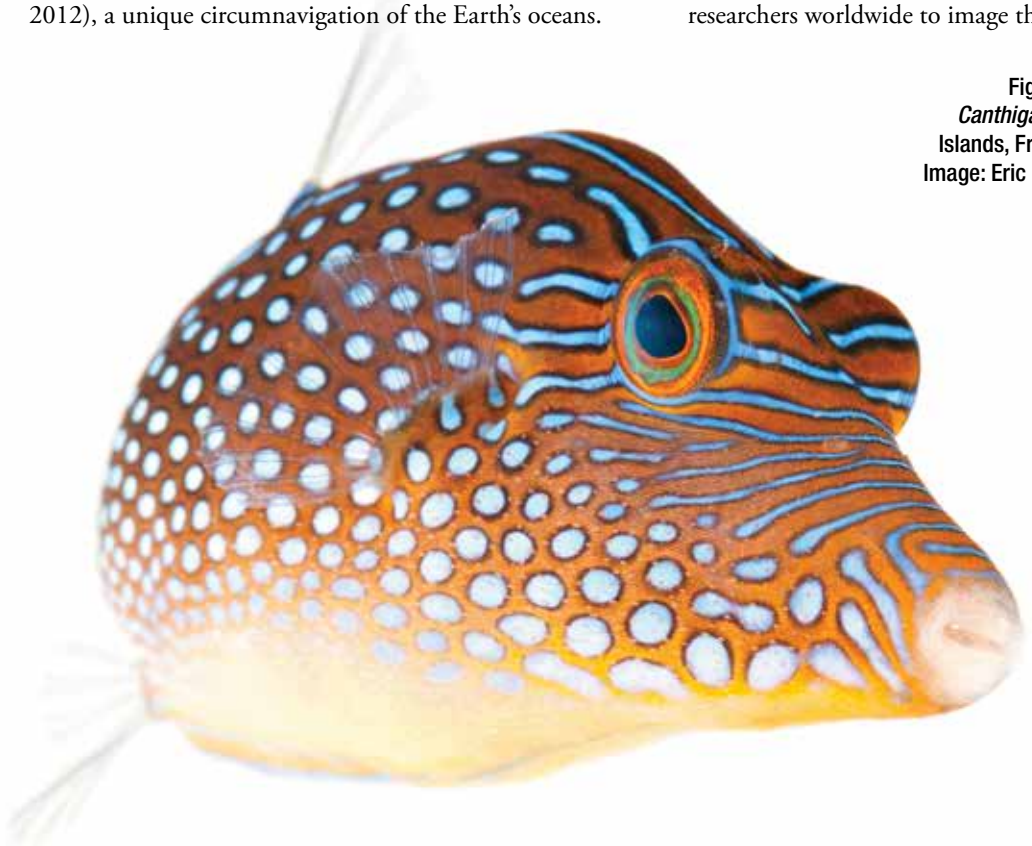

Fig 4. Portrait of the Papuan toby, *Canthigaster papua*. Location: Gambier Islands, French Polynesia. Pacific Ocean. Image: Eric Röttinger / TARA Oceans / Kahi Kai Images.

Kahi Kai **(www.kahikai.org)**

Kahi Kai means 'unique ocean' in Hawaiian and is our French–Hawaiian non-profit organization that aims to make marine science accessible to the general public and students. Our mission is to highlight the connections that exist between all the seas and oceans of the planet and to raise awareness of the fragility of the marine world we all depend on. We develop scientific tools and have launched a project to portray the amazing biodiversity of marine sea creatures around the globe. We imaged more than 1,000 different species alive, giving us the chance to admire their colourful patterns and intriguing behaviour, and released them immediately after the photo session back into their natural habitat (Figures 3 (p. 21) and 4). The images we take are used to illustrate scientific articles, journals and magazines as well as to organize interactive exhibitions around the world. We strive to raise awareness of our shared responsibility to conserve our oceans by introducing the public to the fascinating and diverse organisms found therein. Educating our youngest generation will have the greatest impact as children have a dual role as current consumers and future policy makers. By providing them with a basic understanding and respect for the ocean, and fostering a passion and interest in marine science, we hope to ensure that our future leaders will be capable of making informed decisions regarding ocean conservation.

A new challenge: *Va'a Motu*

Our latest endeavour is ongoing in Fakarava, an atoll

Fig. 5. Kite aerial survey of the northern pass of the Fakarava Atoll using an Ultrafoil 15. Image: Julien Girardot.

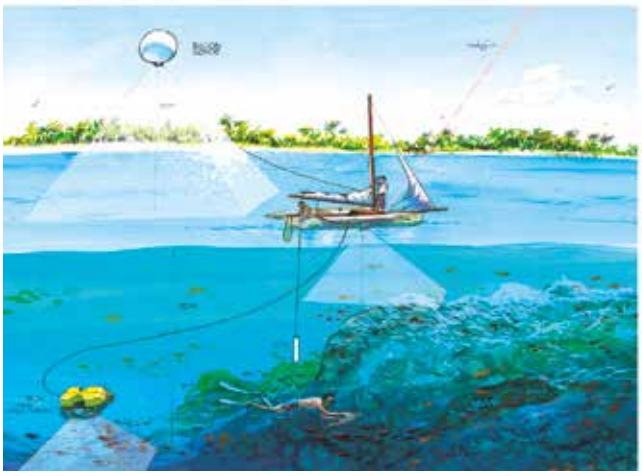

Fig. 6. The Sur *va'a motu*. An artist impression of the scientific part of the project Image: Benjamin Flao.

in the Tuamotu Archipelago of French Polynesia and a UNESCO Biosphere site. There, we helped bring back to life traditional Polynesian sailing canoes named *Va'a Motu*. In close interaction with the local non-governmental organization, we are developing marine surveying systems that can be used on a small *Va'a*. We are combining aerial kite photography (infrared and colour) with small omni-directional underwater cameras and open-source software to create a digital map of the lagoon and its inhabitants (Figures 5 and 6). We use wind and solar energies for our devices (including recharging batteries) to be as carbon-free as possible. We plan to create a complete digital recording of the Fakarava marine life and step closer to our vision while striving to reach carbon neutrality. These tools, specifically designed for the *Va'a*, will become the property of the local community allowing them to regularly map and survey parts of the atoll they wish to follow or zones that maybe used in the future for large developments (e.g. new piers for cruise ships). This citizen science led by the local community and supported by a scientific team is part of our dream, the dream of a Digital Ocean.

Swim long and image well!

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