



tara  
**TARA'S** BLUE BOOK  
FOR THE PACIFIC  
PACIFIC



Fondation  
**taraocéan**  
explore and share

**TARA'S**  
**BLUE BOOK**  
**FOR THE PACIFIC**

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Étienne Bourgois,  
President of the Tara Ocean Foundation

## PREFACE



**ON MAY 28, 2016**, the schooner *Tara* left her home port for a 2 1/2-year expedition across the Pacific Ocean. Her main objective was to collect samples of coral, fish and plankton, as well as numerous physical and chemical data from the planet's largest ocean. The goal was to shed light on the basic mechanisms of adaptation coral reefs have developed to survive the different environmental changes they are confronting: destruction, pollution, urbanization, pressure of tourism and climate change.

**Tara Pacific 2016-2018**, the fourth major expedition of the schooner is in line with the **Tara Ocean Foundation's** missions, through which scientists and sailors intend to improve

our partial knowledge of the Ocean. Today, marine research and its current resources are far too fragmented: science institutions with the effective capacity to explore and innovate can be counted on the fingers of one hand. The vast ocean, representing 71 % of the Earth's surface, remains an unknown environment to discover and describe.

In meeting various cultures and remote territories around the globe, we also tried to share our work with local populations, discuss with both elders and young people, tell them about our observations and future scientific results.

Tara Pacific, an international scientific expedition, will hopefully be the starting point of new ecosystemic approaches, best suited to guide preservation actions. To bear fruit, these actions need to be built upon local knowledge. This is what we have at heart to share in **Tara's Blue Book for the Pacific**: without claiming to be exhaustive, our goal is to help views converge, address together multiple issues and convey solutions already identified by scientists or implemented by the communities encountered from east to west and from south to north in the Pacific Ocean.



tara  
PACIFIC

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# 01

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# TARA PACIFIC, THE EXPEDITION

This mission took place in a context particularly adverse to reef ecosystems. Since 1945, 20 % of coral reefs have disappeared. An additional 35 % are in great danger and may disappear by 2050 (*Status of Coral Reefs of the World, Clive Wilkinson, 2008*). Yet, coral reefs are key ecosystems, home to nearly 25 % of ocean biodiversity. They provide food resources, construction materials and attract tourism, thus sustaining the livelihood of millions of people. Their degradation puts at risk the populations that depend on them.

To assess their health status and understand coral biodiversity, **100 scientists** from **26 research institutions** combined their expertise. Initiated by the **Tara Ocean Foundation** and its partners (**agnès b.**, the **Prince Albert II of Monaco Foundation**, **BillerudKorsnäs**, **Veolia Foundation**, **Lorient Agglomération**, **Brittany region** and **L'Oréal**), this mission brought together researchers from the **CNRS**, **CEA**, **Centre scientifique de Monaco (CSM)**, **Paris Sciences & Lettres University (PSL)** and many other public and private partners.



2016-2018

## THE PACIFIC OCEAN, FROM EAST TO WEST AND FROM SOUTH TO NORTH



**After setting out from her home port, Lorient, on May 28, 2016, the schooner *Tara* returned from the most extensive expedition ever conducted on coral reefs on October 27, 2018. A 2-and-a-half-year journey ended after sailing more than 100,000 km and performing 2,677 scientific dives.**

It was the time necessary to meet our original goal: to explore and study coral reefs on the scale of the world's largest ocean, the Pacific Ocean.

The samples and parameters collected by the Tara Ocean Foundation and its partner scientific institutions will soon produce a unique dataset, essential to multiple research fields to better understand the future of coral reefs. Initiated by the Tara Ocean Foundation, this mission of unprecedented scale was supported by the CNRS, CEA, CSM, PSL University and many other public and private partners.

From the Panama Canal to the South Pacific Ocean and the Japanese Archipelago (2016-2017), then from New Zealand to China (2017-2018), *Tara* traveled and explored a major part of the world's coral reefs. The schooner reached the remotest coral reefs in the South Pacific Ocean (Pitcairn, Samoa, Tuvalu, Kiribati, Wallis and Futuna, etc.), as well as the most urbanized coastal areas of the Asian coast (Taiwan, Japan, Hong Kong, China). She also sailed the "Coral Triangle", hot spot of marine biodiversity (Papua New Guinea, Solomon Islands, Australia, Indonesia, etc.).

From east to west, then from south to north, *Tara's* crew made ports of call in about 30 countries and collected approximately 60,000 samples on numerous sites reflecting various environments and challenges.



# TARA PACIFIC 2016-2018





**RETURN**  
OCTOBER 27 2018

**LORIENT**  
BRITTANY

NORTH  
ATLANTIC  
OCEAN

**START**  
MAY 28 2016

**PORTLAND**  
JUL '18

**BOSTON**  
OCT '18

**NEW YORK**  
SEPT '18

**SAN DIEGO**  
JUL '18

**LA PAZ**  
JUL '18

**MIAMI**  
SEPT '18

**CLIPPERTON**  
AUG '18

**PANAMA**  
SEPT '18

**COCOS ISLAND**  
AUG '18

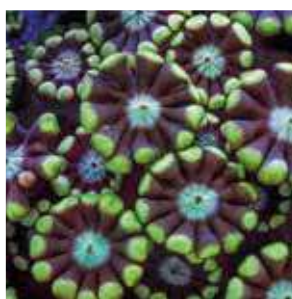
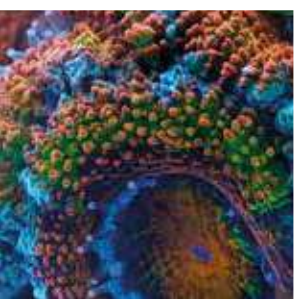
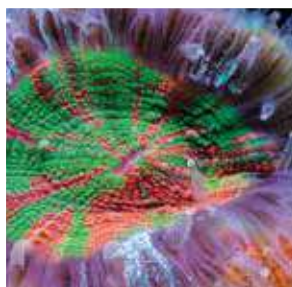
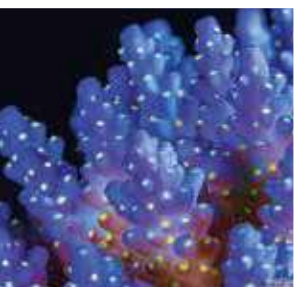
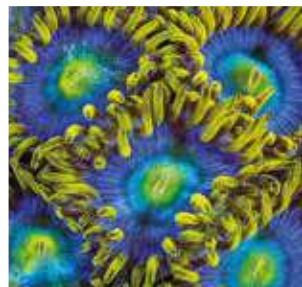
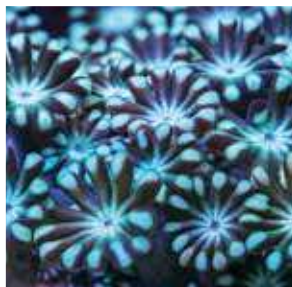
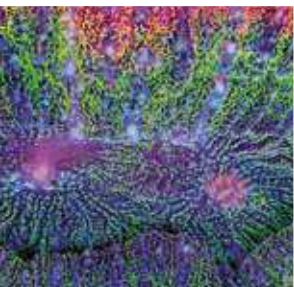
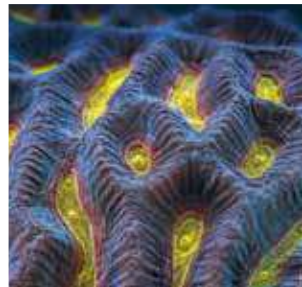
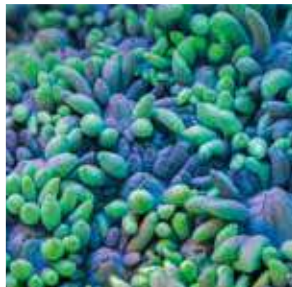
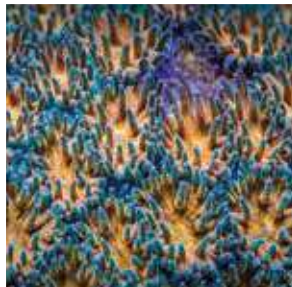
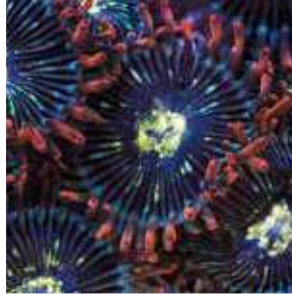
**COLUMBIA**  
JUL '16 - AUG '16

**DUCIE ISLAND**  
SEPT '16

**EASTER ISLAND**  
SEPT '16

### TARA PACIFIC IN NUMBERS:

- More than **100,000 km** traveled
- **883 days** of expedition
- **29 months** of navigation
- About **60,000 samples**
- **70 stopovers** in **30 countries**
- **32 sites** studied
- **2,677 dives**
- **100 scientists** involved
- **23 research institutions**



2016-2018

## WHY STUDY CORAL AND THE PACIFIC OCEAN?



**More than 500 million people worldwide depend directly on coral reefs and their good health.** Coral reefs are one of the most productive and valuable ecosystems on the planet (food, tourism, fishing, etc.). They host approximately 30 % of all currently known marine species, even though their total surface area does not exceed 0.2 % of the ocean's surface. One square kilometer of coral reefs is home to as much macroscopic biodiversity as metropolitan France. Beyond this abundance, coral reefs are a unique ecosystem on our planet.

Like all terrestrial and marine ecosystems, they are impacted by global climate change: increasing ocean temperature – to which coral is highly sensitive – and acidification. They also suffer from direct anthropogenic pressures, such as pollution and destructive fishing techniques. Moreover, in less than 20 years, three quarters of the world population will be living on the coast: pressure on this ecosystem will therefore keep increasing.

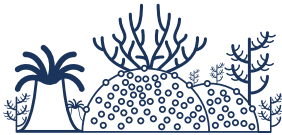
From an ecological point of view, coral's extreme sensitivity to environmental variations make it a very good indicator of the ocean's health. The Pacific Ocean hosts 40 % of the planet's coral reefs and shows an important diversity gradient. In the "Coral Triangle", in Southeast Asia, coral biodiversity reaches its climax.

The coral heritage is essential both ecologically and economically. As a result, the Tara Ocean Foundation decided that this ecosystem, vitally important to humanity would be the subject of an unprecedented mission to address the challenges the Ocean is facing. Its final goals are to understand and anticipate environmental changes at a time of major upheavals and inform policy decision makers to change our relationship with the Ocean.

# THE CORAL REEFS, AN ESSENTIAL BIODIVERSITY TO LIFE ON EARTH

**ABOUT  
1 BILLION**

people worldwide live within 100 km of a coral reef.  
**one person in seven.**



**500 MILLION**

people are directly dependent on coral reefs.

The services they provide to humanity are estimated at about

**\$30 BILLION  
PER YEAR**

Protection of coasts

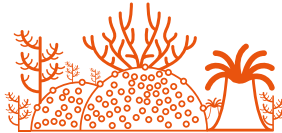


Employment

Food



Tourism



**0,2%**

Coral reefs extend over less than 0.2% of the oceans but they shelter...

**30%**

Animal and plant biodiversity in the oceans.



2016-2018

## WHAT IS A CORAL?



**To understand the goals of the Tara Pacific expedition, we must explain what coral is – this animal that, seen from a distance, looks like a pebble.**

Coral is a unique animal – a kind of small inverted jellyfish – called "polyp", which builds a skeleton outside of its organism. Its particularity also lies in the fact that it can't feed itself. Coral needs to build an association with a micro-alga (*zooxanthella*) to get its energy. Using photosynthesis, this alga provides coral with the necessary nutrients for its survival. Scientists refer to this collaboration between coral and algae as "symbiosis".

This relationship between two very simple organisms has led to the formation of true oases of abundant biodiversity and impressive biological productivity along the coasts and around islands in the intertropical zone worldwide. Additional factors explain this miracle. The main one is called "*island mass effect*". Deep marine currents are affected by the presence of islands, inducing upwelling of deep waters, rich in nutrients. Moreover, mineral elements found on emerged land are regularly carried to the ocean by rain, thus enriching the island's coastal waters in nutrients and mineral salts that benefit phytoplankton and therefore the food chain as a whole. This phenomenon combined with the presence of coral reefs explains the great wealth of reef ecosystems and their expansion all around the planet.

However, coral is a fragile organism. A rise in ocean temperature of only 1 °C can eradicate a reef in a few days. Stressed by heat, coral and algae "divorce". Coral loses its micro-algae, or expels them. Researchers still wonder about this process. Deprived of algae and therefore of nutrients, coral whitens and withers. This is referred to as "bleaching".

## CORAL: ANIMAL, VEGETABLE AND MINERAL

### ZOOXANTHELLAE

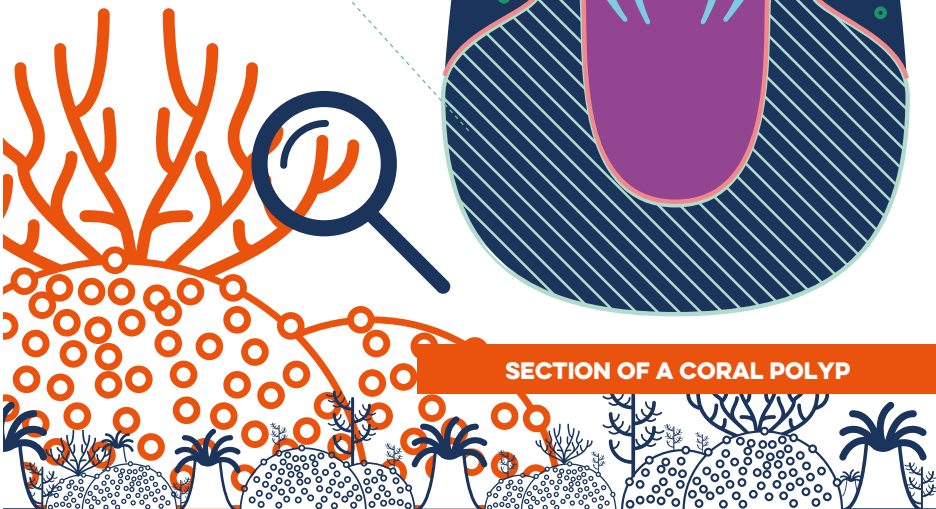
Corals live in harmony (symbiosis) with microscopic algae called *zooxanthellae*. These algae supply up to 90% of the energy necessary to the coral: through the process of photosynthesis, the algae produce sugars and oxygen, essential for coral growth.

### TENTACLES

### MESENTERIC FILAMENTS

**STOMACH**  
(GASTROVASCULAR CAVITY)

**SKELETON OF CALCIUM CARBONATE** (LIMESTONE)

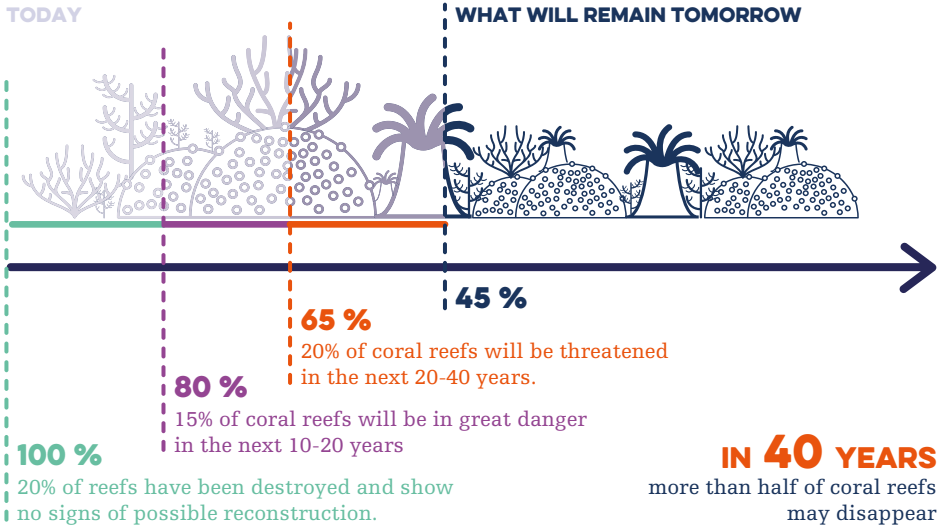


SECTION OF A CORAL POLYP

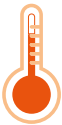




## CORAL REEFS: FRAGILE GIANTS



### MAJOR THREATS: GLOBAL CHANGES



Rising temperatures



Ocean acidification

### MAJOR THREATS: LOCAL THREATS



Pollution



Overfishing



Development of coasts



Sedimentation

2016-2018

## IMPLEMENTING FOUR LINES OF RESEARCH



The Tara Pacific mission is multidisciplinary, combining marine and cell biology, chemistry, ecology, oceanography, genomics and bioinformatics. With data from *Tara's* missions, researchers are developing a new ecosystemic approach to the Ocean on a global scale.

This innovative approach, coupled with advances in genomics (DNA), imaging and big-data processing, augurs new discoveries.

All disciplines included, the scientific consortium focuses on 4 common lines of research:

- **Biodiversity of coral reefs:**

Studying reef biodiversity at different levels of complexity, from genomes to the whole ecosystem.

- **Capabilities of resistance, adaptation and resilience of these environments:**

Exploring how these habitats respond to climate change.

- **Health status of coral reefs confronted with climate change:**

Addressing major questions on the health status of coral reefs in the specific context of climate change by studying islands or islets remote enough to be preserved from sources of anthropogenic disturbances.

- **Reef biology and human health:**

Developing applications for medical research.

## A UNIQUE PROTOCOL



*Porites lobata*

© Lauric Thiault



*Pocillopora meandrina*

© Lauric Thiault



*Millepora platyphylla*

© Lauric Thiault

**To conduct unprecedented *in situ* measurements and samplings, this Pacific-wide campaign mobilized a team and a vessel for over two and a half years.**

Following protocols defined for the whole mission, the teams aboard *Tara* collected in a rigorous and systematic manner – same operators, same equipment evenly calibrated, etc. – numerous samples from various ecosystems across the Pacific Ocean, chosen especially for their geographical remoteness.

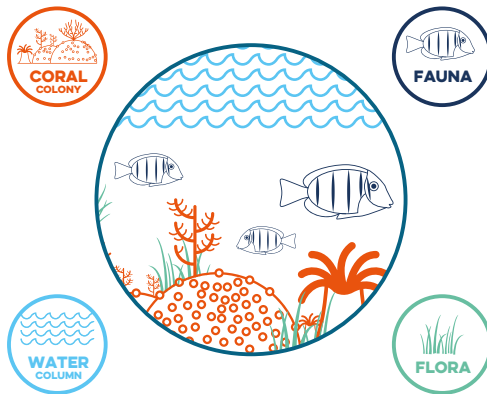
Coral reefs from 32 sites were studied and sampled. The common objectives were to study 3 reference species of coral (see above) and analyze a particular species of reef fish and the surrounding plankton – that is, all the micro-organisms present in the water column or associated with these species.

This meticulous work, carried out by the teams aboard *Tara* for many months, allowed scientists to establish a health status baseline for numerous coral reefs in the Pacific Ocean – a zero point that scientists can refer to in the future to assess the health and general evolution of reefs.



## A UNIQUE, ECOSYSTEMIC APPROACH FOR STUDYING CORAL REEFS

### ON THE CORAL REEFS



• **3 species have been chosen for study** since they are present at all our sampling sites. During the Tara Pacific expedition, **3,000 colonies** will be studied at **100 sites**.

### FOR EACH CORAL REEF:

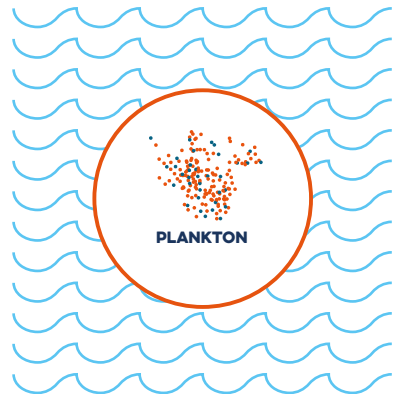
- Sampling of the water column,
- Water samples collected 1 meter above the coral reef,
- Water samples collected within the reef around 2 colonies of the same species

During the Tara Pacific expedition **400 water samples** will be collected at **100 sites**.

- A study of convict surgeonfish (*Acanthurus triostegus*) During the expedition about **1,000 surgeonfish** will be studied.

- **Study of seagrass.** Sampling of seagrass beds at.

### DURING NAVIGATION



On the Tara Pacific expedition, **20,000 samples** will be collected while sailing between coral reefs.

### DURING NAVIGATION BETWEEN CORAL REEFS

- Study of the entire planktonic ecosystem at the surface.
- Collection at the surface of **30 samples** destined for analysis by different laboratories.

## IMPLEMENTED METHODS

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### • Core sampling:

Massive coral such as *Porites lobata* (see previous page) grows 1 cm per year. A 40 cm long core sample tells us about the past 40 years, like an ice core or a tree ring.

Core samples provide a lot of information on the coral they were extracted from and on the surrounding environment. We can thus determine its growth rate during half a century, how the quality of surrounding water has evolved and, more broadly, the health status of coral reefs nearby. These 32 core samples drilled on various reefs of the Pacific Ocean are valuable indicators allowing us to analyze

and better understand parameters related to climate change (for instance, variations in temperature, salinity or acidity (pH)) over the past 50-100 years, and develop useful, if not essential, models to predict current or future climate changes.

### • Physical and chemical parameters:

Like all living organisms, the existence of coral reefs depends on many factors: light, heat, pH, nutrients, oxygen, metals, etc. Each sample is characterized by parameters informing us of the context in which the sample was collected.



## METHODS OF SAMPLING: HARVESTING BY HAND AND CORE SAMPLES

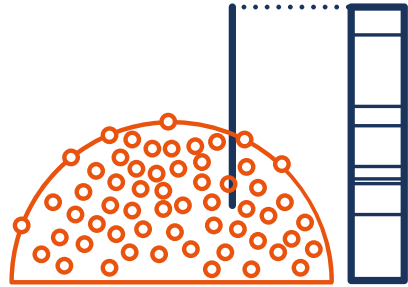
### HARVESTING BY HAND

10 coral fragments (several grams) per colony.



### CORE SAMPLES

The core drill allows us to extract a cylinder of the coral's skeleton from the colony.



### OBJECTIVES

Study, thanks to each fragment, the genetic inheritance and the evolution of coral over time, as well as the **viruses** and **bacteria** hosted by the coral reefs.

### OBJECTIVES

Study the environment in which the coral reef has developed – sunshine, water temperature & acidity, speed of growth of the colony – to better understand its ability to adapt.



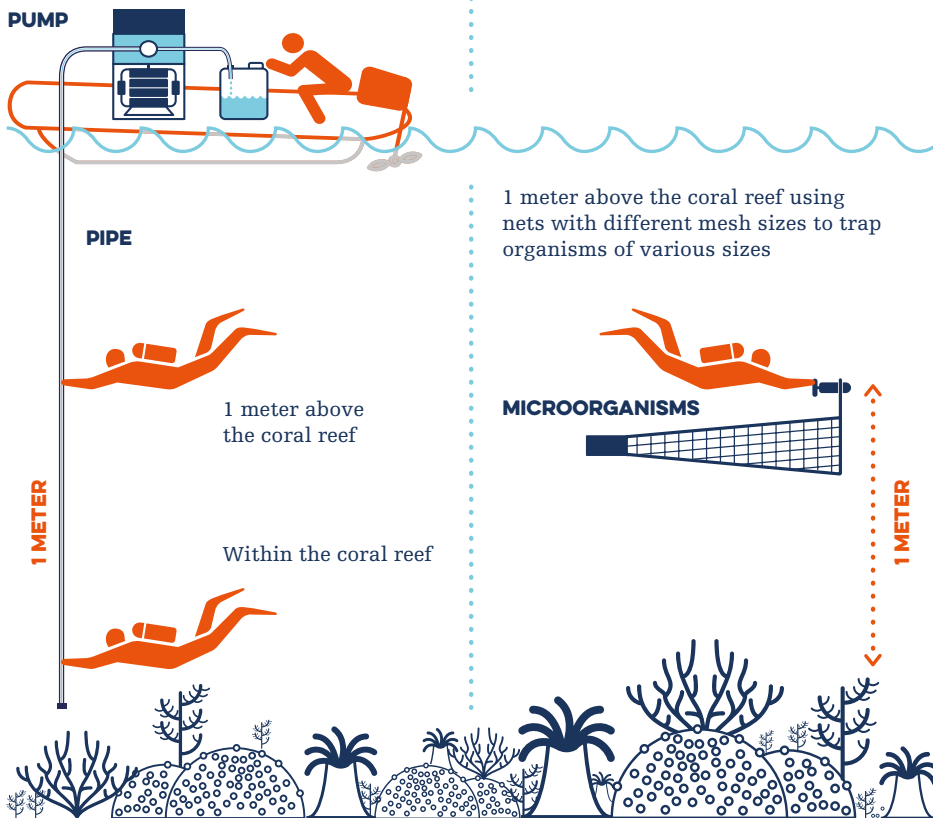
## METHODS OF SAMPLING: SEA WATER AND MICROORGANISMS

### SAMPLING SEA WATER

### COLLECTION OF MICROORGANISMS

#### COMMON OBJECTIVES FOR 2 TYPES OF SAMPLING

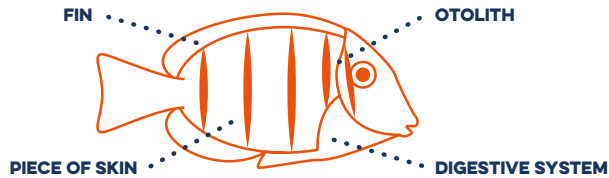
Identify and quantify the different microorganisms present above and within coral reefs in order to study the biodiversity of this ecosystem.



## METHODS OF SAMPLING: REEF FISH AND SURFACE WATER

### SAMPLING OF ONE PARTICULAR SPECIES OF REEF FISH

Samples of the convict surgeonfish (*Acanthurus triostegus*) are collected

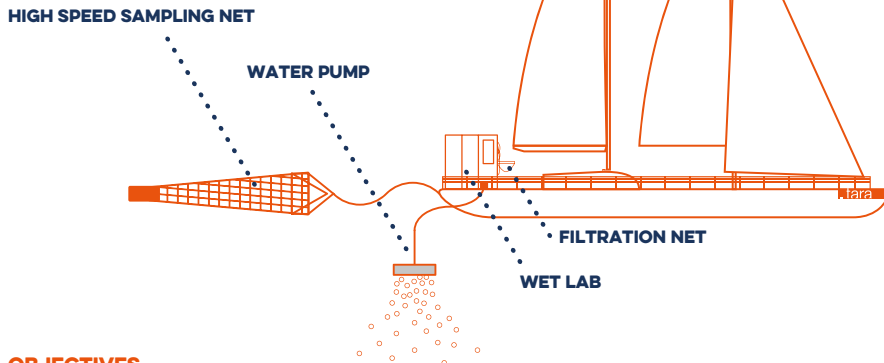


#### OBJECTIVES

Study the ecosystem and environment in which the fish has evolved during its growth.

### COLLECTION OF SURFACE WATER

While sailing between the reefs



#### OBJECTIVES

To collect samples of the entire planktonic ecosystem at the surface, including zooplankton, viruses, and bacteria. Plankton is food for coral. A young coral becomes part of the planktonic eco-system when released into the currents. Studying plankton collected along the schooner's route will provide key information to better understand coral communities of the Pacific and the ex-changes occurring between islands.



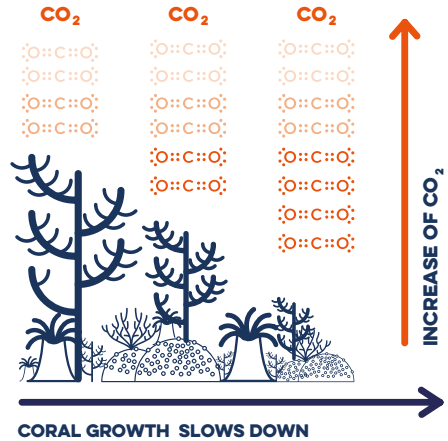
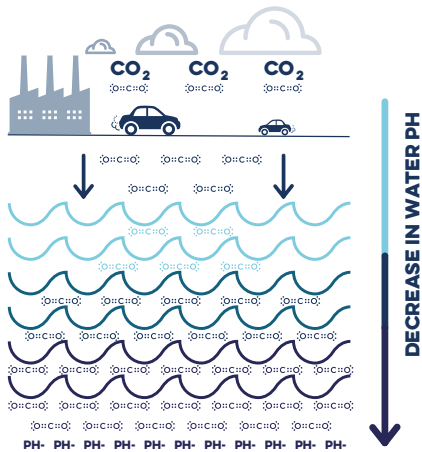
## CORAL BLEACHING: A DIVORCE CASE...

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Exceptional reservoirs of marine biodiversity, coral colonies have a hectic and productive life. This ecological success is made possible by the symbiotic association between two organisms: coral (polyp) and micro-algae (*zooxanthellae*) which provide pigments and nutrients. In other words, the spice of life!

Alas, in periods of warming, a temperature rise can lead to a complete disruption of this relationship. The symbiotic alga and animal then split up. The latter becomes pale, no longer receiving energy, and wastes away. This phenomenon is referred to as bleaching. A rise in temperature of less than 1°C during a few days is enough to cause coral bleaching. This phenomenon can generate significant mortality. If temperatures remain high for 2 to 3 weeks, the polyps, deprived of the sugars provided by the algae, eventually die.





## OCEAN ACIDIFICATION

Acidification represents the other major threat. It's a fairly recent concept, since the first research on the topic was only conducted in the 1990s. The Ocean absorbs more than a third of the atmospheric CO<sub>2</sub> and this leads to an increase in its acidity. Ocean acidification results from the absorption of atmospheric emissions of greenhouse gases. The excess gases disturb ocean chemistry, leading to more acidic waters. Ocean acidification disrupts the formation of coral skeletons and many other biological functions, such as reproduction, calcification and growth rates.





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# 02

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## BETWEEN LAND AND SEA, CONVERGING VIEWS

*Tara's* multiple stopovers during this long expedition, meetings (in particular with local populations directly involved with coral reef issues) and public events organized in the framework of our mission, enabled our multidisciplinary teams to confront in situ various questions related to the preservation of coral reefs. How to preserve coral reefs on a planetary scale? How to raise awareness in countries directly affected by reef degradation and urge them to take concrete and urgent actions to protect coral reefs? Beyond global climate change, how to reduce anthropic activities that cause reef degradation and weaken coral's ability to regenerate? These are some of the many issues our expedition assessed and addressed for more than 2 years.

AUG. 2016



## FIRST 100 SAMPLES COLLECTED IN THE GULF OF PANAMA

By Stéphane Pesant, Oceanographer,  
University of Bremen

**July 27, 2016.** After leaving her home port and crossing the Atlantic Ocean and Panama Canal, *Tara* reached the first coral reefs in the Pacific Ocean, off the coast of Panama. Stéphane Pesant, a biological oceanographer at the Center for Marine Environmental Sciences (University of Bremen, Germany) – the lab in charge of data management – tells us about the first day of sampling.

*"Night is falling on Tara, docked in the Balboa Yacht Club Marina (Panama City), and the scientists who recently boarded the schooner are preparing the first sampling of the expedition.*

*They'll be the last to go to sleep. The crew is already resting in anticipation of a departure during the night.*

*The next morning in the Pearl Archipelago after a night of navigation, the scientists, barely awake, are already reviewing sampling protocols. In the meantime, David Monmarche, divemaster, is completing technical preparations to ensure the safety of the dives.*

*From day one, we have to learn how to work with new protocols and equipment, and coordinate the new team. Though we're putting into practice a new protocol, a considerable amount of work is done. More than 100 samples are collected on 20 different coral colonies, and the underwater scooter allows us to collect valuable plankton samples by filtering seawater around the coral reefs studied. After this successful first day, the 17 crew members trust that the sampling protocol aboard Tara is already reliable. Diving suits are dancing in the wind, drying on Tara's deck. We can hear the laughter and see satisfaction on all faces. It's almost time for a good night's rest: tomorrow a second site will be sampled. About 40 islands across the Pacific Ocean await us."*



SEPT. 2016



## EASTER ISLAND: WELCOME TO FIRST PEOPLES

By André Abreu de Almeida, Director of international policy at the Tara Ocean Foundation

**When *Tara* reached Easter Island, the creation of a marine protected area in the Rapa Nui Natural Park had just been announced by the Chilean government. André Abreu de Almeida, director of international policy at the Tara Ocean Foundation, joined the expedition. A diplomatic support proved to be useful and setting up the Marine Protected Area was very interesting.**

*"Impossible to hide my emotions as I board the plane: my childhood dream is about to come true. We are heading for Santiago and then*

*Easter Island, where Tara has just arrived. A mythical island!*

*Accompanied by 2 Chilean researchers, Alejandro Mass and Maurizio Gonzales, from the Mathematical Modeling Center at the University of Chile, we have the privilege of traveling with Eric Karsenti, distinguished scientist and director of Tara Ocean Foundation's scientific committee.*

*At the airport exit we see local residents holding up signs demanding more autonomy from the government. Welcome to the Pacific, land of indigenous peoples, settlers, independence struggles and constant geopolitical quarrels. The stopover at Rapa Nui (original name of the island) promises to be magical but difficult: the sampling permit for coral has not yet been issued, the sea is rough and on land the Rapa Nui Council of Elders that we are scheduled to meet, is opposing NGOs on the project for a natural park.*

*In the western part of the island, we discover the majestic Moai, stone giants with a penetrating gaze that surprisingly turn their back to the sea. These huge statues, unique in the world, command respect and remind us how ephemeral we are. We then arrive at Anakena beach where Tara is at anchor. Ashore, we meet part of the crew and researchers waiting for the sampling permit to be delivered. This document will eventually be issued after 24 hours of discussion with local and national authorities.*

*Unfortunately, bad weather forces us to cancel the planned dives and public visits.*

*Our meeting ashore with NGOs and elders is important: the Chilean government has just announced the creation of a marine protected area covering the entire perimeter of the island, but disagreements persist between NGOs and rather suspicious elders: the Council of Elders of Rapa Nui wishes to keep managing the natural park and marine protected area.*

*Facing these challenges, we realize how crucial it is to respect the opinion of the local populations.*

*We meet the elders after a session of the peoples' Council of Rapa Nui is held on this subject. They are not very informative and not curious about our missions.*

*Since our stopover, the marine protected area project has been completed by the Chilean government. Officials made sure to include the elders in the project and ensure that people have free access to fishing and traditional activities.*

*Despite harsh weather conditions, this stopover ended with two sunny days, allowing researchers to collect enough samples."*





SEPT. 2016



## TUAMOTU, FIRST MASSIVE BLEACHING EVENTS IN FRENCH POLYNESIA

By Pierre de Parscau,  
onboard correspondent

**Three and a half months after entering the Pacific Ocean, *Tara* completed an unprecedented campaign in the Tuamotu Archipelago, east of Tahiti. The scientific teams carried out two different missions, one focused on coral and the other on fish, while crossing more than a dozen atolls, some of which were completely uninhabited.**

Counting operations, transects and use of the HyperDiver, a prototype of underwater scanner: the schooner deployed many tools under the supervision of Serge Planes, scientific director of the expedition.

After many dives, scientists' findings are irrefutable: Polynesian reefs we thought had been spared so far by climate change have actually undergone profound upheaval.

*"Despite warning systems implemented in particular by the CRIOBE to gather information on the impact of bleaching in the Pacific Ocean, we didn't have much data", explains Serge Planes. "Here, the outer slopes of coral reefs have been seriously damaged and show a high mortality rate. Usually, these reefs consist of 50 to 60 % of living coral. But on the outer slopes and in some areas, it's now less than 5 %. There was important mortality on the Tuamotu reefs."*

The causes underlying the massive bleaching observed are well identified by researchers. The first actor of these climatic disruptions, *El Niño*, is a phenomenon originating off the Peruvian coast and whose hot currents cause an increase in the temperature of the air and therefore of the ocean. On the reefs, this warming generates an important stress in coral populations that gradually lose their symbiotic algae and eventually die from lack of nutrients.

In addition to this phenomenon, human activities also increase global warming and their combined impact can be felt as far as these remote archipelagos. On board, Valeriano Parravicini, a researcher at the CRIOBE

(EPHE-CNRS-UPVD) and reef fish specialist, explains: *"This mortality is widespread, but the coral structures are still in place, even though the coral itself is dead. As a result, the fish community is not strongly affected."*

Of the 7,000 species inhabiting coral reefs worldwide, only about 50 directly depend on coral to feed. For the great majority of reef fish, coral is first and foremost a habitat and a refuge from predators.

If this shelter were to disappear, the reef ecosystem as a whole would be disrupted.

*"If coral dies, a loss in reef biodiversity will occur that can be accelerated by natural catastrophes such as a cyclone. Over time, we'll witness profound transformations and impacts on the fish community,"* he says. Until they learn how marine fauna will adapt to reef transformations, scientists offer reassurance regarding coral's ability to survive these bleaching episodes. In contrast, it is more difficult to assess the consequences of such a situation on Polynesian populations. Concerned island governments, however, fear that the weakening of coral may soon threaten their economies.



NOV.-DEC. 2016

**FROM FRENCH POLYNESIA TO THE  
INDEPENDENT STATE OF SAMOA**By Valérie Puzos-Barbe,  
researcher at the CEA - Genoscope

**In November 2016, we reached the very remote and still poorly documented reefs of Samoa in the South Pacific Ocean.**

We were expecting to discover astonishing marine biodiversity and found that the health status of these reefs was alarming, to the point of not finding any trace of life of the species we were seeking. Scientists now report on a very sad discovery.

*"We arrived in Upolu (main island of Samoa) after collecting samples on the islands of Moorea (French Polynesia), Aitutaki (Cook Islands, country in free association with New Zealand) and Niue (island country in the South Pacific Ocean). We could see that people respect the environment on these islands, both on land and at sea, on the coral reefs.*

*The situation was quite different when we disembarked in Apia (capital of Upolu) and reached the city center where garbage littered the streets and beaches. Once we obtained the necessary authorizations, we anchored near an islet not far away and went free diving to search for the next day's sampling site, as we usually do.*

*Our enthusiasm quickly transformed into dismay. There was no trace of living coral, or very little. We took the dinghy and went a little further. Same finding. We had a quick meeting where everyone expressed their surprise.*

*Maren Ziegler, a researcher at King Abdullah University of Science and Technology and scientific leader of the mission, proposed to make a situational analysis of the ecological disaster we all sensed from our first observations. Equipped with our fins, mask and snorkel, we actively looked for less impacted sites.*

*With considerable stubbornness we went diving at more than 120 sites, covering 83 km along the Upolu coast. We recorded hard coral, micro- and macro-algae, sediments, rocks, and calcareous algae cover.*

*After three days of effort, the verdict fell: we estimated coral cover to be less than 1 % on half of the sites and less than 10 % on almost 80 % of the sites. Only two limited areas, both located in marine protected areas, exhibited a higher*

*coral cover (40-60 %), but still lower than the latest reports we had access to before our arrival. The presence of still intact table-like structures of Acropora and skeletons of branch and massive coral indicated that we were witnessing the fairly recent death of these reefs".*

In Tara's main cabin that day, discussions revolved around the Anthropocene era that we were witnessing.

⋮ Faaite atoll, Tuamotu Archipelago, French Polynesia  
⋮ © François Aurat / Tara Ocean Foundation



NOV. 2016



## CHARLEY WATERS, THE LAGOON GARDENER AND LOCAL SOLUTIONS

By Pierre de Parscau,  
onboard correspondent

### **Appalled to see the lagoon of Aitutaki Island slowly withering, Charley Waters decided to plant coral and giant clams.**

Here, as in many Pacific islands, coral in the lagoon has suffered significant damage caused by chemicals poured on the island's soil, overconsumption of marine resources and increased waste. On Charley's invitation, scientists aboard *Tara* joined the meeting presenting the *Reef Keepers* project.

*"My initial plan was to go to Manihiki, a neighboring island (Cook Islands), but when I discovered the health status of the lagoon here, I realized I had found what I was looking for. What convinced me was the way island inhabitants and government welcomed me. They realized they couldn't save the lagoon with the few resources they had. I had good experience in marine biology and was ready to help them.*

*The fishing tradition has a long history here, and often tradition and science collide with each other. The difficulty is that certain traditional knowledge is not based on science but on beliefs. For instance, some islanders believe that giant clams disappeared from the lagoon because they were jealous of those we introduced. In contrast, without being scientists, some people here have an extraordinary knowledge of the marine ecosystem, reproduction cycles and species behavior.*

*It's essential they understand that it's a virtuous circle: the more coral, the more fish and therefore the better quality of life. I think a lot of school children don't have sufficient knowledge of the lagoon simply because their parents can't afford a mask and a snorkel".*



NOV.-DEC. 2016

## SAMOA, A CLIMATE AND ANTHROPOGENIC SHOCK

By Jean-François Ghiglione,  
a CNRS ecotoxicologist



**Jean-François Ghiglione is a researcher at the CNRS and director of the Observatoire océanographique de Banyuls-sur-Mer.**

*"I had seen images of major bleaching episodes on the Great Barrier Reef in Australia, but personally witnessing this type of disaster, without being prepared, was appalling. After many oceanographic missions, these dives in Samoa were my first "climate shock"."*

*Even if several stress factors are local, we must also take into account global changes to understand the causes of this ecological disaster. Visual pollution of large quantities of macroplastics littering beaches is indicative of a lack of awareness about pollutants flowing directly into the sea via watersheds and waste water that are not processed on the island. The local fishing industry, still using dynamite and various poisons, is intensive, disrespectful of resources and destructive of habitats.*

*Despite efforts of manual collection, an important spreading of *Acanthaster* spp. was observed between 2011 and at least 2015, contributing to the decrease in coral cover. The presence of this devastating starfish is representative of an increase in nutrients coming from the coast and also of the disappearance of predators undergoing strong pressure from the local fishing industry (large fish and neuts).*

*Moreover, all these local disturbances are also exacerbated by changes on a global scale, such as those seen in Samoa. From the collection of satellite data, we have been able to observe that, like other Pacific islands, Samoa has suffered from El Niño in 2015-16, which generated "the 3rd global bleaching event", directly linked to global warming.*

*Our diving suits remained on board! The water temperature was 32 °C and expected to rise. Coral skeletons were still present, letting us imagine a dive site that had once been stunning... now transformed into a cemetery.*

*Unfortunately, exceptionally high temperatures were again recorded in 2017, after our passage. Coupled with the increasing number of tropical storms in the area, this coral reef will soon be reduced to sand."*

After the stopover of the Tara Pacific expedition, a report was drawn up and submitted to the Government of Samoa, hopefully marking the launch of action in favor of coral recovery on the island.

A scientific article was also published in the journal Marine Pollution Bulletin (Ziegler et al., 2018). These reports will help implement a long-term follow-up in this area of the Pacific Ocean.

⋮ Jean-François Ghiglione and Maren Ziegler ready for an early morning dive  
⋮ © Pierre de Parscau / Tara Ocean Foundation





DEC. 2016



### THREE MONTHS OF SAMPLING BETWEEN TAHITI AND WALLIS

By Maren Ziegler, a researcher at the King Abdulla University of Science and Technology (KAUST)

**In Wallis, the team took the opportunity to assess the crossing between the islands of Aitutaki, Niue, Samoa and Wallis and Futuna under the supervision of Maren Ziegler (KAUST). After five weeks of navigation between Tahiti and Wallis, Maren Ziegler gave us a first assessment of the sites studied.**

*"The mission was well honed: we were on a route where we needed to find the same coral species and follow the same protocols every day, as was the case during the entire expedition. It was sometimes very hard to work, the weather conditions were not always good. We started in Moorea where sites are fairly well-known and quite rich in coral. In contrast, in Aitutatki (Cook Islands) we had a big disappointment.*

*When we arrived, we discovered a reef almost entirely dead and had trouble finding sites with living coral to collect. Niue was also poorly known but it was a nice surprise despite the tsunami that had devastated the island in 2009. We actually found a lot of diversity, a good coral cover and damaged areas recovering.*

*In contrast, our last station in Samoa completely upset us: we explored 83 km of coast and had difficulties finding sites with a good coral cover. Most of the species studied had already disappeared. This is a very remote area, not studied on a regular basis, and islanders don't have many resources to access all coastal areas and monitor their situation. I wasn't expecting such a situation."*



JAN. 2017



## TUVALU: AN ARCHIPELAGO ENDANGERED BY CLIMATE CHANGE?

Enele Sopoaga, Prime Minister

### Meeting with Enele Sopoaga, Prime Minister of Tuvalu.

*"We are all on a large canoe, the planet Earth. The way towards saving the world is saving small islands like Tuvalu first. There is increasing awareness and appreciation on the part of the world – particularly those who live in developed, rich and powerful countries – about the fate that the people of Tuvalu are facing due to the impacts of climate change and sea-level rise.*

*It's not fiction. It's not exaggerated. This is real. My home is no longer the island where I grew up. Events and the elements are challenging our security and survival.*

*This makes us more vigilant and incites us to engage more, to better understand the causes and effects of these challenges. Tuvalu and the rest of the world will cope if we work together now. We can't waste any more time denying the actions that have been identified by the scientists and experts working under the IPPC. We have a small window of opportunity to save island economies, maybe even ourselves, if we commit to working together. I cannot accept that the people of Tuvalu will be regarded as "environmental refugees" or "climate change refugees". I think these are naive references by people who have no idea what climate change and its impacts really are. We'll paddle together. Let's paddle together. If we save Tuvalu, we save the world."*



## MARCH 2017



## SHIKINEJIMA, A NATURAL LABORATORY IN JAPAN

By Sylvain Agostini, a marine biologist at the University of Tsukuba

**In March 2017, the Tara Pacific expedition reached the Japanese Archipelago. The government had already announced that the reefs of Okinawa Island had suffered a major bleaching event affecting 70 % of the total coral cover.**

**Before going there, the schooner made a stopover on the island of Shikine, a very singular site, ideal to understand the future of reefs.**

In collaboration with 6 Japanese universities, *Tara* sailed along the Pacific Coast, from the north to the south of the archipelago, where the marine current Kuroshio flows. This current carries warm tropical waters to high latitudes, thus bathing coral reefs and the northern temperate rocky coasts.

The geographical situation of these coral colonies is quite unusual and provides important data and parameters allowing scientists to understand how coral adapt to 2 major stress factors: global warming and ocean acidification. These changes cause organisms to migrate to higher latitudes and upset the establishment of coral colonies.

These high latitudes, made habitable by the increase in temperature, may shelter coral in the future. Unfortunately, the increase in atmospheric CO<sub>2</sub> also leads to a reduction of seawater pH. In Shikine, underwater volcanic CO<sub>2</sub> emissions alter ocean chemistry, generating physical and chemical conditions similar to those predicted in the future due to ocean acidification. A phenomenon making coral growth more difficult and limiting their "migration" towards high latitudes.

Shikine, an island of the Izu Archipelago, is therefore an ideal laboratory for in situ modeling. The data collected will provide key elements to answer important questions such as: How and where will colonies settle in the future?

In the event of a northward migration, will ocean acidification be too high to allow coral adaptation to new environments?

How will fauna and flora react to reefs normally providing shelter and food to 30 % of marine biodiversity?

In the event of coral "migration", what will the impacted areas become?







MARCH 2017

## NICOLAS FLOC'H: ARTIFICIAL REEFS IN BLACK AND WHITE

By Noëlie Pansiot,  
onboard correspondent



**Originally from Brittany, Nicolas Floc'h joined the crew during our stopover in Tokyo. He is a visual artist and teacher at the European Academy of Art in Brittany. For a month, he was diving alongside Tara scientists, exploring coral. Interview with an artist-in-residence.**

**The ocean is your favorite subject. Can you tell us about your career?**

*"When I was 12, I dreamed of becoming a fisherman. At age 14, I was a seasonal fisherman at*

*La Turballe. At 17, I quit school and embarked on fishing boats for a year. Then I went back to high school and university, and took a master's degree at the Glasgow School of Art. I do sculpture, installations, photography and video, but also performance art. The sea is one of the themes that goes through all my work".*

**You embarked in Japan, a country you already know...**

"Yes indeed. I've been working on a project about artificial reefs since 2010. An artificial reef is a structure in metal or concrete, immersed between 10 and 80 m deep, which is intended to restore degraded habitats or produce biomass. In Japan there are whole submerged cities. It's estimated that there are 20,000 sites below the surface with several thousand or even tens of thousands of reefs per site and towers up to 35 m high. True underwater urbanization!"

**What is the purpose of your work on artificial reefs?**

*"I'm taking inventory of these architectures and producing a documentary work in volume, in sculpture. I reproduce them before immersion, in the same materials, but at a tenth of the actual size. Once placed underwater, these structures are transformed and are no longer accessible. I also dive around the submerged structures to document and photograph them.*

MARCH 2017

*This work on artificial reefs helped me to understand how they function, but also to observe their advantages and disadvantages. There is no ideal system, but over the course of my research. I found that they generate biomass and provide sustainable shelter. And I think we can't measure their role only in terms of habitat. These artificial reefs also change fishing practices. Once immersed, these enormous structures leave no room for trawling. The way of fishing has changed: line or traps are used – more gentle fishing techniques, resulting in more sustainable fishing. This change of methods interests me".*

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JUNE 2017



## FIJI ISLANDS: TARA AMBASSADOR OF THE UNITED NATIONS OCEAN CONFERENCE

By André Abreu de Almeida,  
International Policy Director of the Tara  
Ocean Foundation

**During the Paris COP21 in 2015, *Tara* and the Ocean and Climate Platform joined forces with other ocean supporters to hold a UN conference entirely dedicated to the ocean. In 2016, the governments of Fiji and Sweden announced its implementation and their wish that it be held in Suva, capital of Fiji Islands.**

This Conference was finally held at the UN Headquarters in New York. *Tara* nevertheless maintained the planned stopover in Fiji,

and participated, in Suva, in an international conference promoted by the FFEM – French Facility for Global Environment, the French Embassy and the University of the South Pacific. This conference, entitled "Pacific Voices for a Global Ocean Challenge", was held on June 7 and 8, 2017 – as was the "official" conference in New York. The main objective of the Suva conference was to define a clear message – on a Pacific scale – about the regional measures to be implemented for safe-guarding the ocean, and in addition, to raise public awareness of the urgency to preserve the strongly damaged coral reefs. Many organizations and regional partners were invited to contribute to the debates and propose their own suggestions, enabling the voices of the Pacific peoples to be heard.

During the first session, the debate revolved around the delicate subject of sustainable policies and their application. Various local actors presented their visions but also their concerns about the impact of climate change on a regional scale.

The second session featured numerous scientific projects and examples of successful projects for sustainable management of marine resources in the Pacific region. The scientists came from all over the Pacific and presented their work on a wide variety of topics: ocean acidification, coral bleaching,

plastic pollution and the essential role of marine and coastal ecosystems (plankton, corals, seagrass, etc.).

Along with eminent scientists, Serge Planes, scientific director of Tara Pacific, outlined the objectives of the expedition and the main innovations developed during the research on the reefs. Guillaume Bourdin, engineer responsible for the plankton section of the mission, reported on what the first year of the expedition had taught us about the planktonic ecosystems associated with coral reefs.

Participants in the closing session of the conference focused on understanding how climate change can interact with lifestyles specific to Pacific populations. There were numerous exchanges on this theme with many representatives of these peoples with different traditions: old, young, artists, poets and ordinary citizens of Fiji and neighbouring islands.

During the stopover in Fiji, the schooner also welcomed aboard representatives of the traditional peoples. On this occasion, short videos were produced and broadcast during the official United Nations Conference in New York. We are convinced that the people of the Pacific, the first to be impacted by global warming, must participate more in discussions aimed at developing sustainable solutions to combat effects as quickly as possible.

Locally, *Tara* and the FFEM teamed up with the University of the South Pacific to create an exhibition. The "Ocean Regulates Climate" exhibition, composed of photographs, graphics, and researchers' testimonies, was hosted by the Oceania Art Gallery of the University of the South Pacific from 6 to 14 June 2017. Visitors could learn about marine and coastal ecosystems – their biodiversity, ability to self-regulate, the complexity of their interactions, and their contribution to enhancing the stability and resilience of our planet.

With an International Conference, an exhibition, the projection of films and many visits of the general public and school groups, *Tara's* stopover in Fiji was extremely productive. It helped policymakers and a large audience to better understand the role of Pacific Ocean ecosystems in the climate. During this stopover, we understood the importance of taking into account the "Oceanic people" in the political decisions of the 21<sup>st</sup> century.



JULY 2017

## E-POPERS: TESTIMONIES FROM PACIFIC YOUTH FACING CLIMATE CHANGE

By Noëlie Pansiot,  
onboard correspondent



**The e-PoP Project (Petite Ondes Participatives), brings together young reporters/observers from Oceania, Africa and the Caribbean.** Their goal: to gather the opinions of the populations on environmental changes and the preservation of insular and coastal environments. With few technical means, the young e-PoP observers go out to meet the people who experience the global changes in their daily lives.

Using a simple mobile phone, they collect and record the testimonies of people who are ordinarily forgotten by the media because of their isolation or lack of means of communication.

This project was conceived by RFI Planète Radio, France Media Monde's cooperation arm. In partnership with the IRD, the Tara Ocean Foundation welcomed a young observer from New Zealand. Interview with Max Bale, head of RFI Planète Radio and co-founder of the e-PoP network.

### Can you explain the purpose of the project?

*"The e-PoP project wants to be participative and PoPular! We are interested in the consequences of environmental, economic and human changes. It's a project that creates a link between the people, the scientific world and the political world, to communicate the reality and sentiments of the island populations. In concrete terms, e-PoP is an international network of young people who produce audiovisual vignettes to capture the feelings of local populations in the face of the consequences of global warming. To collect the impressions and record interviews of the older generations (often relatives or members of their families), to have sincere exchanges, then to question the scientific world and*

*push them to give understandable responses to the feelings expressed by these elders who have seen the changes with their own eyes, and who live with them on a daily basis. There is a real humanistic and intergenerational approach in this project, and also the desire to feed the archives of the intangible heritage of humanity for this continent, already heavily impacted by climate change. Through this network, we try to feed the reflection of scientists and policy makers on the consequences of global warming, but also to see if the laws and decrees take into account the feelings of the populations. We also try to advance the knowledge of local populations, for whom the scientific notions of global change don't mean very much. At the dawn of the 21<sup>st</sup> century, scientific notions are not often described in terms that are understandable for poorly educated populations."*

**What does it take to be a good e-PoPer?**

*"Motivation and commitment! As Pericles said: "There is no happiness without freedom, nor freedom without courage." The e-PoPers are young people who have the courage to get up in the morning and instead of turning on their television, they take out their phone to capture and report what's happening in the world, in insular and coastal environments. Some e-PoPers work with first-generation phones. We manage to do a lot with little."*

**The project is therefore participative and voluntary?**

*"It's 600 % volunteer! Planet Radio is used to working in relatively difficult countries: in Africa, but also in Cuba, Timor, etc. We offer our support and ensure that the voice of the people is heard by decision makers. We give voice to local, often isolated communities, so they can make themselves heard with the means at hand: small local radio, local media, associations, etc. The impact of the current changes on populations is measurable in daily life."*

*Some communities have to leave their ancestral living areas to cope with the rising waters, others find that the fish are smaller, that they must go further out to fish, and with fewer fish to sell, they have more difficult living conditions. These testimonies, these feelings of the old people interest us: they have life experience but are rarely given the chance to speak about it. We're mainly talking about the inhabitants of islands, island states and coastal areas who are directly impacted by global warming and global changes."*

*We try to put human beings at the heart of the problem. It's really a militant and civic approach! "*



OCT. 2017

## SOLOMON ISLANDS: IN THE EYE OF CLIMATE CHANGE

Interview by Vincent Hilaire,  
onboard correspondent



From Honiara, the capital of the Solomon Islands, to Kimbe Bay ("Coral Triangle") in Papua New Guinea, we welcomed Joe Frazer Piduru, an observer from the Solomon Islands, aboard *Tara*.

This smiling 43-year-old man born in the province of Choiseul, one of the big islands of the archipelago, is a professional sailor. He holds a Master Class 4 certificate, obtained at the Honiara Merchant Marine School. Joe works for the Solomon Islands Maritime Safety Administration (SIMSA), the equivalent of Maritime Affairs in France.

*Tara* is anchored a few hundred meters from a palm tree forest that extends almost to the beach. Plumes of smoke emerge above some of the tree tops. A tribe lives there. Further out on the water, men are fishing from pirogues.

While the new scientific team prepares its first dive here, 40 nautical miles northwest of Honiara, through his rectangular black sunglasses, the newcomer looks discreetly at the scene: loading the pneumatic dinghy, one of the rituals of the *Tara* Pacific expedition orchestrated by the sailors using the crane.

The Solomon-Papua leg is just beginning. Here's the opportunity to get to know Joe better by asking him some questions.

**Several hundred islands make up the Solomon Archipelago. Which one do you come from?**

*"I was born in the province of Choiseul, like my parents. Our tribe has an island along the coast of Choiseul, it is our customary territory. The island's name is Zenoa. We managed to have it classified as a marine protected area in 2010, and we're waiting now to benefit from a conservation program."*

**Why did you take these steps to protect your island?**

*"We want to protect Zenoa and all the species living there, but also the reefs. We are doing this for the future, so that there is a future. In recent years, we have seen the disappearance of many fish species. We do not know why. Maybe it's climate change or overfishing or overexploitation of our forest resources, or maybe all three together?"*

**Overfishing and climate change – we're discovering more consequences every day in the world. But how does the overexploitation of the forest impact the sea and reefs for example?**

*"The first of the disturbances comes from a very significant increase in maritime traffic. Many freighters from Malaysia come to load wood here, very often near the coast which doesn't have a particular port structure. They also want to avoid paying port taxes, so they drop anchor and destroy the sea bed with their anchors. Logging generates very large quantities of sludge. This mud then runs down the slopes, carried by the rivers, before emptying into the sea. This causes massive pollution and destroys the ecosystem. This sludge is loaded with oil and hydrocarbons of all kinds. Exploitation of gold leads to further damage, with mines and the dumping of heavy chemicals into our coastal waters. The problem is that all the islands of our archipelago have this type*

*of exploitation. It's been 40 years that we've been cutting wood here – cutting down trees that absorb CO<sub>2</sub> and release oxygen – and polluting the sea."*

**What are the authorities doing about this situation?**

*"We want to stop this horror. The problem of logging is corruption. In the ministries here, everyone is ready to sign an authorization for exploitation in exchange for a bribe. The government has only managed to classify fewer than 10 wood species in 40 years. If we don't protect our forests more we'll destroy them, but also our lagoons, our reefs and all their biodiversity. I am sure that this deforestation has consequences for our climate here."*

**What changes have you noticed these past years for your climate? Remember there was Cyclone Pam in 2015.**

*"From our elders we inherited an understanding of our local climates, but now it doesn't apply anymore. Today there's bright sun and tomorrow there can be a cyclone. We are affected by climate change and our climate is no longer stable as before. As for cyclone PAM, it mainly affected the Vanuatu and the eastern part of the archipelago, the province of Temotu. Here we suffered less. But now, two years later, thanks to the massive number of supply ships that arrived after the tragedy, everything is back to normal."*

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*The only thing that improved after the tragedy is that now we have mobile phones to warn people. We have weather stations in the 9 provinces, but they do not all work.*

*Another manifestation of the consequences of climate change is that we're starting to see islands disappear.*

*The first one disappeared in 1999, in the Russel Islands archipelago, because of rising waters and violent tropical storms.*

*Our situation is very bad, we are trapped. When I was little, I looked underwater, everything was ok. I swam in the middle of the fish. I played in crystal clear waters. But nobody taught us to protect our forests, our fish, our corals. This must change, we must change."*

”



NOV. 2017

## DEEP MINING

By Noëlie Pansiot,  
onboard correspondent



**Helen Rosenbaum, founder of the "Deep Sea Mining" campaign, is working with various organizations in Papua New Guinea to end the Solwara 1 project, an underwater mining project.**

*"Solwara 1 is the first mine on the ocean floor in the world to have a mining license. The mine is located in the Bismarck Sea in Papua New Guinea, in the archipelago of the same name.*

*One of our concerns with the mining of hydrothermal vents is the destruction of these unique ecosystems, even before scientists have been able to study them.*

*The mining process, in itself, generates sediment plumes suspended in the water. However, neighboring coastal communities depend on fishing to survive! The Solwara 1 mine site is approximately 60 km from Rabaul in eastern New Britain, only 25 km from the coast of the province of New Ireland, and approximately 40 km from the Duke of York Islands. It's right in the middle of traditional fishing areas – island and coastal communities for whom fishing is their livelihood. Anything that enters into the food chain will affect them. In addition, these communities exchange their fish with people living inland.*

*These communities have not given their informed consent to this project – a fundamental right established in the UN Declaration. They should be able to freely give their consent before the project is put in place."*



NOV. 2017



## RITUAL MEETINGS IN PAPUAN LANDS

By Vincent Hilaire,  
onboard correspondent

**After leaving Alotau midday on November 1<sup>st</sup>, 2017, we sailed north-east for 80 km, before reaching Normanby Island. We anchored at nightfall and the next morning experienced the first ritual meeting of this stopover. Many others would certainly follow.**

At 7:30 local time, when the sun had been grazing the tropical forest for over an hour, we launched one of the dinghies to go ashore and meet our hosts.

Half an hour before, pirogues paddled by children and adolescents were already turning around *Tara*, curious, with absolutely no animosity.

Embarked in the dinghy, an improvised delegation, led by our captain Simon Rigal, and our Papuan scientific observer, Alfred Yohang Ko'ou, landed on Soba Island. The children of this community were thrilled. The adults were more withdrawn, waiting to experience this first contact. We were led to two huts, one on the ground and the other on stilts, both constructed mainly of braided palm leaves. Sitting on the floor around a palm mat brought from the main hut and unfurled for us in front of the whole family, among dogs, chickens and a pig, the meeting began.

Alfred started by explaining in Papuan where we came from and what we were doing aboard *Tara*, while showing on his blue T-shirt our route from France. Kana-gola, the head of the community, listened attentively. Then, our current scientific leader, Rebecca "Beckie" Vega Thurber, explained more precisely our scientific interest for this bay and what we would like to do there. The leader was still listening, very calm, his face expressing no particular reaction.

Suddenly, he blurted out to say, *"Ah, the bubbles!"*

Beckie explained that a mission had already come in 2013 to carry out research work on these bubbles, CO<sub>2</sub> bubbles that emanate from the seabed and are of interest to scientists. Kanagola nodded. Beckie continued, *"Today we come to make a new campaign on these bubbles of carbon dioxide and their consequences on the coral ecosystem. We will then compare these new results with the older ones. The ocean is acidifying right now, and you have an exceptional laboratory at the end of your beach. Kanagola was reassured: "I give you permission to do what you have to do here. But if you go to the next bay, you have to ask the other community for their agreement."*

Simon Rigal pulled out of his backpack some Tara Junior magazines in English and gave them to Kanagola, explaining with a touch of humor, that *"these are magazines for children, but as an adult I learned lots of things from them"*. Kanagola thanked Simon with a smile.

The meeting was coming to an end. Permission was given to us to take some photos of this traditional way of life, with no water or electricity.



## ROMAIN TROUBLÉ

Executive director  
of the Tara Ocean Foundation

*"When the Tara Pacific expedition was set up in 2015, just after COP21, the statistics on recent coral bleaching events had not been made public. That same year, the El Niño phenomenon had a major impact on coral reefs, so our mission became especially important. We found ourselves at the forefront of the international scientific scene, taking on the heavy task of assessing the effects of this deadly phenomenon (still poorly known) by sailing very close to the islands, islets and atolls of the entire Pacific Ocean."*

DEC. 2017



## POLITICAL ISSUES AND AUTHORIZATIONS

By Romain Troublé, Executive director  
of the Tara Ocean Foundation

**The schooner *Tara* reached Indonesia in December 2017.** Unfortunately, we were not able to continue our research in the territorial waters of the archipelago for lack of authorization from the government. This aspect of Tara expeditions is one of the most complex to solve. During the preparation of the mission, many diplomats declared that it would be impossible to accomplish the research in thirty countries consecutively. Indeed, two licenses are required for each country: a first research license to explore the waters of another country, defined by the Convention on the Law of the Sea of 1982; and a second license,

called CITES – *Convention on International Trade in Endangered Species of Wild Fauna and Flora* – for the import-export of samples, coral being a family of protected species. The Washington Convention on International Trade in Endangered Wildlife requires an export permit from the country where sampling takes place. *Tara* would be collecting samples for 5 days, then leave the country in question the next day with samples on board. The Foundation had to obtain the export authorization on one day, for the following day. We acknowledge the great efficiency of the National Museum of Natural History (Paris) in doing this. Like all research vessels at sea, *Tara* evolves on a geopolitical chessboard. The sovereignty of countries is strong and relations between states can sometimes be tense. While freedom of navigation is a fundamental right at sea, authorizations are sometimes difficult to obtain. Requests for underwater research pose multiple questions: security, protection of resources against bio-prospection, international scientific cooperation and therefore many different ministries are mobilized. Six months are not always enough, requests can be lost, authorities don't always understand the files, don't answer them, or refuse them without explanations.

On land, Clémentine Moulin, responsible for logistics at the Tara Ocean Foundation in Paris, devotes her days and sometimes her nights to this.



2016-2018

## EDUCATIONAL GOALS: FROM BOAT TO SCHOOL, LEARNING ABOUT THE OCEAN



**With more than 70 stopovers in nearly 30 countries, *Tara* shared with a great number of people the environmental challenges affecting the Ocean.**

Everywhere the team met the locals and, often among them, the children who came with their classes. In total, nearly 7,000 young people in 17 cities visited the schooner for a discovery of science, boat and crew.

On land, and more specifically in classrooms, in partnership with the National Education, the Tara Ocean Foundation allows teachers

to build a broad educational program over several months. *Tara* arouses curiosity and young people are ready to go on an adventure, in search of knowledge. Some also find their vocation.

Sources of inspiration for teachers have been multiple and varied: videoconferences with researchers, journalistic investigations of "Seeds of Scientific Reporters" on the ocean and the climate, scientific data kits collected during *Tara's* missions, "Carnets de labos" to better understand the scientific instruments, their functioning, scientific documentaries on the key themes of *Tara* (plankton, coral, plastic waste) and experiments to be done in class, among others.

All these original resources have been turned into educational activities by teams of teachers-authors and filtered through the official programs of the National Education to stick to the objectives and skills expected. They are available free online on the website of the Tara Ocean Foundation, for the educational community.

For the "Echoes from Stopovers" operation, a trunk of souvenirs contains an object associated with each of *Tara's* stopovers, for example, an air mask that raises the question of air pollution in China. Young visitors were able to take a world tour of the local

sustainable development issues encountered by *Tara's* crew during their mission.

Thanks to videoconferences and digitized resources, dozens of French-speaking high schools around the world shared *Tara's* educational adventure. Through their classroom activities, young people experience life-size ocean issues while sharpening their critical thinking and scientific spirit. They can marvel at the biodiversity and fragility of the oceans and be inspired to take action when they discover under *Tara's* microscope the microplastics invading our seas.

The schooner's scientific adventure is a powerful lever for interdisciplinary education, reflecting the reality of scientific investigation. The *Tara* team is welcomed with open arms in the Academies and teacher training is an opportunity to bring the Ocean into the schools. *Tara's* outreach programmes involve teachers at all levels and disciplines, promising long-term projects with a whole generation of young people: an educational adventure from boat to school and from school to boat.



### IN SUMMARY:

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- 700 teachers trained during the period of the expedition,
- 20,000 students following educational programs with the resources of the Tara Ocean Foundation in their classes,
- 11,800 have met a mediator in class or in conferences in France,
- 7,000 visited the boat during stopovers.

### SINCE THE BEGINNING OF THE TARA PROJECT:

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- Outreach involved 50,000 youths at various meetings, class work, and about 15,000 at stopovers.
  - In 2018, 388,000 children, potentially sensitized to the preservation of the ocean in partnership with the operations of Mickey Beach Clubs during the summer, through the Oceans by Disney program.
  - The Tara Ocean Foundation also collaborates closely with educational partners including La Main à la Pâte, l'Ademe, and others.
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# 03

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# OBSERVATIONS AND FIRST LESSONS

After these first observations, it is clear that the future state of coral reefs and the ecosystem services they provide to people will depend mainly on the trajectory of global CO<sub>2</sub> emissions and our capacity to enhance the resilience of these reefs, in particular through management of local stressors, they are reversible in the short term.

The expedition was completed in October 2018 and the last samples were sent to the laboratories. At this stage of the mission – a huge database is being built and research is just beginning. The following observations are by no means exhaustive. Despite the great disparity in the health status of the reefs, there are major trends in different geographical areas.

Current trends show a transition that favors massive corals at the expense of branched corals. This is a radical transformation, with a loss of diversity, at least local, and especially the loss of habitat diversity. Massive corals (Porites and others) show superior resilience to different stresses and may dominate in the future, giving way to a depleted reef in terms of diversity.



2016-2018



## THE PATCHWORK OF PACIFIC CORAL

### BETWEEN CLIMATE CHANGE AND LOCAL THREATS

**During these two years**, Tara Pacific's teams witnessed numerous episodes of coral bleaching. Linked primarily to global warming, this is a process in which heat-stressed corals separate from beneficial algae (symbiotic micro-algae) that provide them with nutrients.

At Ducie Island, west of Easter Island in November 2016 and then in Moorea – French Polynesia – the following month, the crew observed for the first time, reefs strongly impacted by global warming.

While the mission focuses primarily on the biological responses of coral to environmental upheavals, the crew made several observations:

- In Polynesia, bleaching has reached 30 to 50 % in some Tuamotu islands,
- At some sites, nearly 70 % of the coral cover was affected by bleaching, as seen at Ducie, near Pitcairn,
- In Samoa, bleaching had reached 90 % and resulted in the massive death of coral colonies (estimated in 2016),
- In Micronesia, Tuvalu Islands and Kiribati, some of the reefs had already died before *Tara* arrived,
- The reefs of Wallis and Futuna have been relatively preserved,
- In the north Pacific, in more temperate waters, the reefs did not escape bleaching: up to 70 % in Okinawa, Japan.

While predictions indicate that 25 % of coral reefs will disappear and that 50 % are at high risk compared to 25 % in good health, it is actually very difficult to make accurate estimates because of the disparity in observations made on a Pacific scale.



It should be noted that coral reefs are very diverse between Panama and Indonesia. Their compositions vary, and the areas *Tara* traveled through in the Pacific Ocean were dotted with numerous reef islands spread over vast territories.

In fact, the expedition covered very different ecosystems, each subjected to various types of stress and impacted by multiple local and/or global anthropogenic pressures. In other words, some of these islands are subject to direct and local disturbances such as fishing, pollution and urbanization, but others are far away from any source of anthropogenic pollution.

All are potentially subject to the global changes of warming and acidification (CO<sub>2</sub>). The challenge of the research carried out during the *Tara* Pacific expedition was notably to take into account these different contexts to measure disturbances on the reefs, to distinguish the impacts, the responses and the adaptation capacities of the reefs.

**5 distinct examples to illustrate this coral patchwork. From the small island of Ducie to the mega-city of Hong Kong, and Japan – let's explore the health of the Pacific's coral reefs.**



**SAMOA ISLANDS, DOUBLE JEOPARDY FOR CORAL** - NOV'-DEC' 16

**HONG KONG, CORAL IN THE CITY** - MAR' 18

**PALAU, ACIDIFICATION AND WARMING: CORAL PUTS UP RESISTANCE** - JAN' 18

**CHESTERFIELD ISLANDS, A JEWEL OF INTACT BIODIVERSITY** - SEPT' 17

- HONG KONG** 7-15 MAR' 18
- SANYA** FEB' 18
- VIETNAM** FEB' 18
- SHANGHAI** 15-29 APR' 18
- KEELUNG** 21-23 MAR' 17
- JAPAN** 4-19 MAY 18
- OGASAWARA** FEB' 17
- MARIANNES** JAN'-FEB' 17
- MICRONESIA** JAN' 17
- KIRIBATI** JAN' 17
- TUVALU** JAN' 17
- KIMBE BAY** NOV' 17
- SALOMON** OGT' 17
- INDONESIA** DEC' 17
- MILNE BAY** NOV' 17
- CHESTERFIELD ISLANDS** SEPT' 17
- NOUMEA** SEPT' 17
- FIJI** JUN' 17
- NIUE** NOV' 16
- SAMOA ISLANDS** NOV'-DEC' 16
- HAWAII** JUN' 18
- AUCKLAND** JUN'-AUG' 17
- GREAT BARRIER REEF** SEPT' 17
- SYDNEY** AUG' 17

# CORAL PATCHWORK



**DUCIE ISLAND: HEAT WAVE ON HEALTHY REEFS - SEPT '16**

SEPT. 2016



### DUCIE ISLAND: HEAT WAVE ON HEALTHY REEFS

#### PITCAIRN ISLANDS, SOUTH PACIFIC

**Ducie Island** is a small uninhabited atoll located in the southern Pacific Ocean, approximately 535 kilometers east of Pitcairn Island. The island and the central lagoon occupy only 4 km<sup>2</sup> and are 1,500 km south of Easter Island.

This atoll – one of the most isolated and southern in the world – is home to many different species of birds and marine species, including coral reefs.

Because of their extreme isolation, the reefs along the Ducie coastline were considered an example of intact habitat, where the exploitation of marine resources did not take place.

In 2012, very good coral cover of more than 50 % was observed. The health of the coral reefs was considered excellent and no bleaching had been documented.

In 2016, when the Tara Pacific expedition returned, the reef still covered an extensive area. But the divers discovered a high level of bleaching, so severe that the reef was entirely white, like a marine ossuary. If the bleaching of 2016 was not unique, this vast expanse of coral would suggest a good recovery capacity for the reefs on Ducie Island, which bodes well for the persistence of the coral ecosystem on this site.

NOV.-DEC. 2016



## SAMOA ISLANDS, DOUBLE JEOPARDY FOR CORAL

SAMOA,  
SOUTH PACIFIC

**Samoa is well known and appreciated by divers.** The geographical location left hope for a well-preserved reef and the available data such as satellite images converged towards a great wealth of coral ecosystems. Although some signs of bleaching had already been observed in November 2016, the state of the Upolu reefs was very badly degraded: the coral cover had become less than 10 % on more than 80 % of the 124 sites observed during the expedition.

According to scientists, this situation is explained by the combination of global and local factors. On the one hand, global warming has increased the impact of the classic *El Niño* climate cycle (in 2015-2016) resulting in massive coral bleaching. On the other hand, local human activities would exacerbate the effects of climate change: in sites where anthropogenic pressure is important, 30 to 40 % of dead corals are already covered with macro-algae. The release of chemicals, sewage, garbage and overfishing could impact the ability of already weakened or damaged corals to recover from a bleaching episode.

Conversely, scientists observed healthier reefs east of the island, in the heart of a marine protected area, a sign of the effectiveness of certain management methods.

These observations led to an article published in April 2018 in the journal *Marine Pollution Bulletin*.

SEPT. 2017



## CHESTERFIELD ISLANDS, A JEWEL OF INTACT BIODIVERSITY

### CHESTERFIELD, NORTH WEST OF NEW CALEDONIA

**In September 2017**, *Tara* reached the Chesterfield Islands, a French archipelago located in the Coral Sea, 550 km north-east of New Caledonia and 900 km from the Great Barrier Reef. Scientists observed a pristine coral ecosystem surrounded by crystal clear water, sharks, schools of tuna and other large fish. The coral cover was very high, greater than 80 %.

This archipelago is home to a truly extraordinary biodiversity, where the corals are in very good health.

It seems that they were not affected by the bleaching wave (*El Niño* 2015-2016, extended in 2017) responsible for the disappearance of about 30 % of coral cover in the Great Barrier Reef. One of the reasons might be physical factors that prevented the water from warming up, that is, cold currents and winds. Another hypothesis for the researchers is the unique situation of the Chesterfield Islands.

Indeed, the archipelago is uninhabited and therefore subject to no pressure due to local human activities, such as pollution, fishing and tourism. As a favorable factor for reefs, hundreds of birds on the site produce a considerable amount of guano (bird droppings) which contains high levels of nitrogen, phosphate and potassium that fertilize these nutrient-poor waters. The absence of bleaching, diseases and the presence of massive corals, whose age varies from one hundred to one thousand years, should give insight into the vitality of these coral reefs.

JAN. 2018



## PALAU, ACIDIFICATION AND WARMING: CORAL PUTS UP RESISTANCE

MICRONESIA,  
WEST CENTRAL PACIFIC

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**The archipelago of Palau** is composed of 500 islands, only a few inhabited.

With water temperature about 29 °C all year round, the Republic of Palau is home to about 500 species of corals. Absolute protection of the natural environment has been written into the Constitution since Palau became an independent nation. Environmental protection is even taught in primary school!

One of the particularities of this archipelago is the presence of underwater sources of CO<sub>2</sub>, making these sites a true natural laboratory where scientists can study the adaptation of coral to ocean acidification. The pH of these sites is about 7.9 (instead of the typical 8.1) which is the pH predicted for the year 2100.

In Palau the reefs and corals were in good health during our stay. Coral diversity was high, including many fragile and endangered branching species. Despite natural acidification, this ecosystem appeared in good health.



## MARCH 2018



## HONG KONG, CORAL IN THE CITY

### SOUTH EAST ASIA, NORTH WEST PACIFIC

**With more than 7 million inhabitants,** Hong Kong is a densely urbanized region. Nearby, the Pearl River carries huge volumes of wastewater from the world's largest urban area (in size and population) into the sea. In the Pearl River delta, marine habitats are under heavy pressure from human activities – rapid coastal development, overexploitation and pollution.

High levels of nutrients, cloudy water, and ubiquitous plastic waste associated with extensive agricultural exploitation have led to the degradation of coral reefs. Skeletons of severely eroded coral, abundance of diseases and of animals associated with corals, near absence of fish, the coral diversity is very low.

But compared to other regions, the few species of coral found in this area seem little affected so far by the rise in temperatures. Today, Hong Kong's very few corals are considered particularly resistant because they have been able to cope with the temperatures, levels of salinity and sediment loads that corals elsewhere cannot withstand. Considered to be the Pacific's most resistant biodiversity, Hong Kong's marine life has become extremely poor.

## TAKE ACTION!

### TARA'S SOLUTIONS FOR PROTECTING THE REEFS

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#### 1 - IMPROVE THE MANAGEMENT OF WASTE, ESPECIALLY PLASTIC WASTE

Macro and microplastics carry invasive species – viruses and bacteria – that risk inducing pathologies in coral. Solutions to prevent plastic pollution at sea are found on land! We need to limit single-use plastics, create new materials more respectful of the oceans, and innovate to develop a circular economy. Better management of waste, especially plastic waste, is possible in the very short term.

#### 2 - LIMIT THE IMPACT OF AGRICULTURAL AND INDUSTRIAL EFFLUENTS

Wastewater from livestock farming, effluents from agricultural and industrial sources contain various organic and chemical components, including pesticides that are harmful to the environment. Due to their toxicity and capacity to disrupt ecosystems on land and in the sea (including coral), effluents deteriorate the health of the lagoons and must be subjected to increased vigilance.

#### 3 - LIMIT DEFORESTATION AND PREVENT SOIL EROSION

Forestry activities can have a huge impact on corals: Clearing land for cultivation causes runoff, especially during periods

of heavy rainfall. Runoff carries sediments that cover the reefs, reducing their exposure to sunlight, vital for coral.

#### 4 - PROHIBIT OR LIMIT THE MOST DESTRUCTIVE FISHING METHODS

Trawling, dynamiting and using cyanide are among the fishing techniques that destroy marine ecosystems. Some countries have banned these techniques, but others continue to practice them. Each explosion with dynamite can irreparably ravage up to 20 meters of reefs.

#### 5 - BETTER MANAGEMENT OF SHORELINES

Coastal and watershed management is increasingly necessary for improving the health of coral reefs. In the face of global population growth, coastlines are becoming increasingly developed, with tourist complexes, industrial ports, bridges, houses on the seashore, dikes, etc. It is crucial to take environmental criteria into account when developing large coastal infrastructures.

#### 6 - INVOLVE LOCAL POPULATIONS, RAISE PUBLIC AWARENES

We must involve at a very young age the people who live on reefs and depend on them for their livelihood. Only in this way will they take responsibility for protecting their own environment.

2016-2018

## POLLUTION, URBANIZATION, FISHING, COASTAL MANAGEMENT: LOCAL FACTORS ARE BROUGHT TO LIGHT

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The health status of coral reefs is highly variable – determined by the stresses they experience, usually at a local scale. Studying the entire area of the Pacific, scientists found a wide variety of conditions: healthy reefs, degraded reefs and even some that were rebuilding themselves. At present it's difficult to make accurate predictions about the evolution of these ecosystems because their state of health depends on various impacts: direct human activities, global warming, or the cumulative effect of these 2 factors. Tara Pacific's data will help dissociate the effects of local disturbances (pollution, urbanization, sedimentation due to soil erosion) from the impact of global changes (global warming, acidification), and measure the health of coral populations subject to both types of disruption.





## **TURN-OVER OF CORAL SPECIES: MAJOR CHANGES IN THE NEXT DECADES**

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The original Tara Pacific data will tell us which factors favor the resistance of coral species. These data should make it possible to identify optimal conditions for ensuring corals' survival, in function of the environmental parameters and corals' biological parameters and microbiota (viruses, bacteria, etc.).

In the coming decades, some species will be seen less frequently than others that are common today. In other words, species abundant today are the ones for which present conditions are ideal. In the future, the environment will become favorable for the development of other species. This suggests profound changes in coral reefs over the next two decades and hence in the entire food chain and associated ecosystem.

2016-2018

## THE IMPACT OF GLOBAL WARMING ON CORALS

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Once bleached, corals soon succumb to disease or "die from starvation". In the past, episodes of coral bleaching were caused by the El Niño phenomenon, but recent events are different. They are caused by a combination of factors associated with global warming, including a context that scientists call « *warm blods* ». These hot water bubbles cause bleaching of a regional nature and are irregular, as recently observed on the Australian Great Barrier Reef, where in 2016 bleaching occurred mainly in the north.

⋮ Bleached corals at Tuamotu, French Polynesia  
⋮ © David Hannan – Ocean Ark Alliance / Tara Ocean Foundation





..... Diving on the reefs of Ducie Island  
..... © Pete West / Tara Ocean Foundation

The world is getting warmer and coral bleaching episodes are becoming more common. Scientists predict that bleaching will become an annual phenomenon in the coming decades. Some recent projections show that between now and the year 2055, 90 % of the world's coral reefs will undergo a severe bleaching episode each year. Though this phenomenon does not signify the death of a coral colony, the reduction of respite time between two bleaching episodes limits the ability of mature corals to fully recover, a process that typically takes 10 to 15 years.

To date, predictions of coral reef evolution no longer foresee their complete disappearance by 2050, but suggest that reefs will degrade until the end of the current century, until climate change stabilizes and new types of reef assemblages develop that can withstand the new thermal conditions of the planet.



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# 04

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# FROM RESEARCH TO OCEAN PRESERVATION

The **Tara Pacific** database (which scientists will produce following the expedition) will assemble a mass of diverse and integrated information that promises to shed light on the mechanisms of resistance and adaptation developed by reefs – for example, how they confront various forms of stress. Scientists will apprehend the coral reef as a whole, because corals are not merely colonies of animals called polyps. Corals are complex biological systems known as “holobionts”.

These systems develop thanks to a complex balance consisting of viruses, bacteria, algae and other microorganisms living inside or upon the coral polyps. These “microbes” and micro-organisms are indispensable to the polyps.

Marine biologists have increasingly adopted the holobiont concept over the past 10 years. Studies of these complex biological systems have made possible some of the most important discoveries in recent years. **Tara Pacific** scientists hope to understand the equilibrium of the coral ecosystem through its microbial life



2016-2018



## A GLOBAL APPROACH TO PLANETARY CHALLENGES

By Romain Troublé, executive director of the Tara Ocean Foundation

**Climate change, loss of biodiversity, species migration – the Tara Foundation is helping provide answers to planetary challenges.**

Some scientific questions call for approaches that encompass the complexity of the Ocean's evolution. This is what characterizes the Tara Pacific expedition: a global approach and unique data collected on an unprecedented scale.

The exceptional character of this expedition is its ecosystemic approach – multidisciplinary and "transversal" – with the participation of coral biologists, geneticists, oceanographers, specialists in plankton and reef fish, bio-informaticians and even medical doctors!

Until now, such an approach has never been achieved on such a vast geographical scale. Fortunately, a great deal of local research on coral reefs has already been conducted. The Tara Pacific expedition traversed a very wide gradient of biodiversity, reaching a maximum in the "Coral Triangle" – Indonesia, Papua New Guinea, Solomon Islands – considered the most diversified region in biodiversity. About 10 species of coral are found in the eastern Pacific Ocean (Gulf of Panama), but there are about 400 species in the "Coral Triangle".

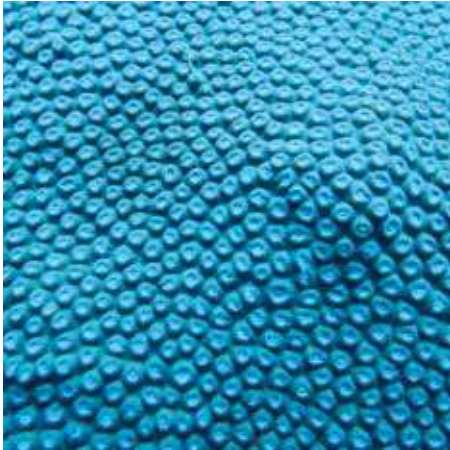
With nearly 60,000 new samples, the integrated Ocean ecosystem database assembled year after year by Tara Expeditions, will benefit from an important update, and will be an exceptional contribution to the history of exploration and research. Collected on 32 coral sites, sometimes located more than 13,000 km apart, the data will inspire a comparative and interdisciplinary approach on a very broad scale.

The Tara Oceans expedition (2009-2013) generated the largest database ever acquired on the planktonic ecosystem from the surface to a depth of 1000 meters. Using the same methods of sequencing, sampling, data processing and bioinformatic analysis, the Tara Pacific expedition (2016-2018) will allow us to describe the microorganisms of coral reefs and their still-unknown interactions.

Tara Pacific will provide the international scientific community with a unique database on coral reefs, revealing the genomic, genetic, viral and bacterial biodiversity of each reef. This makes it possible to focus research on comparative, statistical, and even quantitative approaches, and ultimately to study the connectivity between offshore planktonic ecosystems and coastal reef ecosystems.



2016-2018

**REEF DNA:  
A HISTORY BOOK  
OF MARINE  
BIODIVERSITY**

**A fundamental approach of Tara Pacific is the DNA and RNA sequencing (done by the Genoscope, CEA) of nearly all 60,000 samples of corals, plankton and fish collected during the expedition.**

Carrying the genetic code, DNA is an essential source of information for studying corals. It makes it possible to precisely identify the different species using marker genes, then provide information on the metabolism and evolution of the organisms.

RNA reflects the levels of expression of each gene in an organism. We can thus identify the ones particularly active in a given environment, and those that have become extinct. RNA studies will reveal coral activity at the time of sampling and, by comparing the different samples, help us understand mechanisms governing the organisms' capacity to adapt to environmental variations. In addition, DNA and RNA will be used to study interactions between organisms, that is, how bacteria, viruses and microalgae affect coral survival. By studying correlations between the abundance of species and expression of their genes, we can find the genes important in the establishment and maintenance of symbiosis.

The biological and genomic complexity gradually being revealed should provide scientists with crucial information for understanding the inner workings of coral reef systems. It also suggests an interesting future for reef conservation.

2016-2018

## THE MINION: FOR THE FIRST TIME AT SEA, A POCKET DNA SEQUENCER CAN ANALYZE CORALS IN SITU



Most genetic analyses on coral samples require large and highly sensitive laboratory equipment that cannot be installed on a boat like *Tara*. Samples must therefore be stored on board until they are sent to partner laboratories to be analyzed, several months after collection. Such delays prompted researchers to use a new sequencing technology, the nanopore, which allows DNA to be analyzed directly at the sampling site, in less than 48 hours.

This technique is based on a sequencer the size of a large USB key, the *MinION*. Aboard *Tara* in Papua New Guinea, in November 2017, the *MinION* was used for the first time to describe corals that are extremely diverse in this region. At present, this technology doesn't allow a complete DNA analysis of corals with complex genomes, but we can identify them by sequencing specifically targeted marker genes. Since identification of different coral species is sometimes impossible with the naked eye, using DNA can be essential. Furthermore, the *MinION* allows us to study the diversity of micro-organisms (algae and bacteria) living inside the coral colony which can have a strong influence on its survival. In Papua, 45 corals were thus analyzed, providing a global vision of the microbial diversity present in this isolated reef's corals, and informing us about its state of health. The ultimate goal is twofold: to carry out a maximum of analyses on the spot and thereby reduce the number of samples being transported to laboratories. And also to obtain a preliminary on-site analysis in order to reorient sampling towards the most interesting coral colonies for further analyses.

2016-2018

**FROM CORAL  
TO HUMAN HEALTH**

Corals offer a particularly interesting field of study for research on aging and age-related diseases because these animals have an extraordinary capacity for tissue regeneration and strong resistance to stress, combined with extreme longevity. The tips of chromosomes, called telomeres, play a key role in the aging of many organisms, including humans.

The role of telomeres in the capacity for adaptation and extreme longevity of coral are still unknown. Scientists at the Institute for Research on Cancer and Aging of Nice (IRCAN) are trying to understand if variations in coral's telomeres are related to environmental factors, and whether or not they depend on the rich biodiversity observed within the coral ecosystem and its "microbial universe" (microbiota). This research is expected to reveal new biological mechanisms controlling stress resistance that could eventually be transposed to human medicine for preventing and treating age-related diseases such as cancers, neurodegenerative diseases, diabetes and cardiovascular illnesses.

**CORAL,  
DNA AND BIG DATA**

Tara Pacific data are being organized in a way similar to the world-wide collection of plankton samples by Tara Oceans (2009-2013). The coral data will enrich a global database allowing researchers to work on the connectivity of organisms between reefs and the open sea, and ask questions that we have not imagined yet. The size of the database will encourage vast and qualitative statistical approaches. A new era of oceanography, incorporating biological Big Data, is opening up and will constantly require more data. The use of "citizen science", including Tara's Plankton Planet project ([www.planktonplanet.org](http://www.planktonplanet.org)) is the logical next step. Similarly, the use of artificial intelligence seems inevitable to understand, model and better preserve the Ocean, as the mathematician and French deputy Cedric Villani notes in his Report on Artificial Intelligence ([www.aiforhumanity.fr](http://www.aiforhumanity.fr)). These colossal datasets (more than 90 Terabytes of DNA data and 30 Terabytes of images of planktonic organisms) are available in free access via European databases. They now provide the most comprehensive description of a global ecosystem, allowing us to model the future of that ecosystem.

2016-2018



## PIERCING THE MYSTERIES OF CORAL'S MICROBIAL ENVIRONMENT

**What role do "microbes" play in coral's adaptation to global warming and local disturbances?**

What functions do they have, these hundreds of thousands of micro-organisms living inside and on these corals?

While the corals themselves grow and reproduce relatively slowly, do the micro-organisms present alongside them evolve too?

Do they adapt to changing environments?  
Are they able to protect the corals?

One of the major innovative goals of future research will be to understand the microbial functioning of this ecosystem, unveil the interactions between the micro-organisms, viruses, bacteria, algae, etc. – sort of "amniotic fluid" of coral – to measure its adaptability to an evolving, changing environment.

2016-2018

## INITIATIVES TO PROTECT AND SUSTAINABLY MANAGE CORAL REEFS AND THEIR ASSOCIATED ECOSYSTEMS

In addition to local and national initiatives implemented by cities and governments, it is important to foster the emergence of regional projects. A coral reef is never completely immune to impacts coming from far beyond its close environment. Proof is the presence of plastic fragments in corals, even in the most remote and presumably preserved places on the planet.

The International Coral Reef Initiative (ICRI) is a unique partnership of governments, international and inter-governmental organizations, scientific entities and non-governmental organizations. Composed of about 80 members, it has been chaired since July 2018 by Australia, Indonesia and the Principality of Monaco.

ICRI has been working for more than 25 years to implement and promote actions to preserve coral reefs and related ecosystems all over the world from degradation.



A French version of the ICRI, the French Initiative for Coral Reefs (IFRECOR) brings together all the national stakeholders concerned by coral reefs and the French overseas territories where these ecosystems are present: New Caledonia, French Polynesia and Wallis and Futuna in the Pacific; Guadeloupe, St. Martin, Martinique and St. Barthelemy in the Atlantic; Reunion, Mayotte and the Scattered Islands of French Southern and Antarctic Lands in the Indian Ocean.

IFRECOR's mission is to strengthen knowledge; develop networks for monitoring the health status of coral reefs, mangroves and seagrass; protect and sustainably manage these unique and fragile ecosystems.

2016-2018

## MARINE PROTECTED AREAS: A GOOD TOOL THAT DOESN'T FIX EVERYTHING

**To preserve coral reefs** from various threats including mass tourism and pollution from ships – the creation of a Marine Protected Area around the reefs remains undoubtedly one of the most effective solutions.

Defining a perimeter of protection governed by restrictive access rules is an effective

way to protect reefs from direct human impacts. Marine Protected Areas may not prevent all the problems in the field (particularly those related to land-based pollution), but the results are positive. The numerous reefs classified as zones of reinforced protection – subjects of careful followup studies – provide very concrete proof.

In order to achieve better long-term results, the means for managing and monitoring Marine Protected Areas must be supported and strengthened.





## 2020-2030

**2020-2030: MAJOR POLITICAL DEADLINES FOR PROTECTION OF THE REEFS**

For the Tara Ocean Foundation, the *UN Agenda 2030*, dedicated to sustainable development, is the opportunity for new actions. Starting in 2020, several UN summits and conferences are planned on issues related to the preservation of coral reefs.

**1 • In 2020**, the revision of the Biodiversity Conservation Objectives will be held in China during the COP15 Convention on Biodiversity. Its main objective will be to define actions to be undertaken for the creation of Marine Protected Areas, with objectives set until 2030.

**2 • In June 2020**, coral reefs will also be on the agenda of the 2<sup>nd</sup> United Nations Ocean Conference in Lisbon: the Roadmap for Sustainable Development Goals (SDGs) will be established for 2020 to 2030.

**3 • In the framework of the Climate Change Conference**, a first revision of National Contributions (NDC) for implementation of the Paris Agreement will happen in 2020, allowing important measures to be put in place for the preservation of the Ocean, and its coral, within the climate agenda of each country.

In addition to global efforts, the Tara Ocean Foundation also calls for the implementation of actions at the local level to mitigate direct stress on reefs.

Without masking the urgency of reducing greenhouse gas emissions, we must actively combat factors that are directly destroying coral reefs: proliferation of plastic waste, unsustainable tourism in lagoons, oil spills, and the development of major coastal infrastructures.

**FRANCE, ON THE FRONT LINE**

The data and analysis produced by the Tara Pacific expedition will be readily available and used to inform and support policy decisions. France, with treasures of overseas territories, has in its territorial waters nearly 10 % of the world's surface coral (5,000 km of linear reefs, 60,000 km of reefs and lagoons). The objectives announced in the Biodiversity Law of 2016, with laudable ambitions – to protect 75 % of coral reefs by 2021 and 100 % in 2025 (according to article 113-2) – must develop a plan for taking specific actions. The stakes are known and widely documented in the ICRI's assessment of reefs and associated ecosystems state of health. It's time to take action!

OCT. 2017



## DECLARATION FOR PROTECTION OF CORAL REEFS

*Coral Reef Life* is a declaration for the protection of coral reefs, proposed by **HSH Prince Albert II of Monaco** and supported by the Tara Ocean Foundation at the *Our Ocean* conference on October 5-6, 2017 in Malta.

**"Coral reefs are threatened with extinction by climate change and human activities.** To protect them, the *Coral Reef Life* Declaration encourages the signatory countries, on a voluntary basis, to follow these 10 measures:

**1 • Participate in the 3<sup>rd</sup> International Coral Reef Year (IYOR 2018)** and show that coral reefs are a key indicator of the health of the oceans and the planet,

**2 • Implement the Paris Agreement** and national solutions to prevent damage to coral reefs. Through protection and conservation, help the people dependent on reefs to adapt to climate change,

**3 • Encourage the Intergovernmental Panel on Climate Change (IPCC)** to focus on the role and fate of coral ecosystems; to explore and promote solutions to be included in its 2019 Special Report on climate change, oceans and the cryosphere,

**4 • Promote multidisciplinary research** on recent coral bleaching events to understand their mechanisms of resilience and adaptation, better predict future events, and guide public policy,

**5 • Support strategies for adaptation and local management** to increase the resilience of coral reefs at the regional level,

**6 • Help develop models of responsible business** working for the health of coral in the private sector,

**7 • Help companies** reduce the risks of investment related to coral,

**8 • Promote financial investment** in coral reefs and the benefits of a sustainable Blue economy,

**9 • Ask the hosts of the 5<sup>th</sup> Our Ocean Conference** to plan a plenary session on how to improve the resilience of coral ecosystems,

**10 • Invite other countries to join** this declaration."



# CONCLUSION

The objective of the **Tara Ocean Foundation** is to provide high-level scientific expertise to inform environmental policies. The more we know about the resilience mechanisms of reefs, the better scientists will be able to advise policy makers and the people involved in reef restoration.

The data from **Tara Pacific** could help at the local level to specifically preserve certain reefs, by showing which human activities are the most damaging to corals. What factors, or combinations of factors, have led to a considerable reduction of coral distribution in certain regions? These data can be invaluable for coastal management to enable sustainable urbanization and effective protection of marine habitats. Isolating the stress factors should help to understand how to guide policies to restore coral biodiversity in the very short term.

The **Tara Ocean Foundation** is recognized as **Special Observer at the United Nations** and acts to inform policy makers in the field of ocean governance. The Foundation provides, for example, scientific expertise during international negotiations.

## TARA PACIFIC



### TARA PACIFIC: SCIENTIFIC OBJECTIVES BEYOND THE EXPEDITION

By Serge Planes and Denis Allemand,  
Scientific co-directeurs of the  
Tara Pacific expedition

**Reefs provide men and women living nearby with benefits known as ecosystem services.** More than 500 million people worldwide depend directly on the survival of coral reefs. Tourism and fishing – corals are one of the most productive and valuable ecosystems on the planet. Coral reefs are home to about one-third of all marine species known to date, even though the total surface of the reefs does not exceed 0.2 % of the ocean's surface.

This means 1 in 3 inhabitants of the Ocean! On 1 km<sup>2</sup> of coral reef, we find as much macroscopic biodiversity as in all metropolitan France. Reefs are a unique ecosystem on Earth. With a wealth of overseas territories, France has in its territorial waters nearly 10 % of the world's coral surface: 5,000 km of linear reefs and 60,000 km<sup>2</sup> of reefs and lagoons, including the second longest barrier reef in the world (after Australia's Great Barrier Reef) – the New Caledonia barrier. With the objectives announced as part of the biodiversity law of 2016 – to protect 75 % of coral reefs by 2021, and 100 % by 2025 (art 113-2) – France has laudable ambitions, including a plan of action that should be implemented within the framework of the French Initiative for Coral Reefs (IFRECOR).

Like all ecosystems, terrestrial and marine, coral reefs are affected by global climate change: the warming of the oceans (to which coral is highly sensitive) but also their acidification. Today, coral bleaching, a process triggered by a small increase in the temperature of seawater (an increase of 0.5 to 1 °C above a certain threshold is enough to cause this phenomenon) is the only phenomenon induced by global warming whose effects are visible to the naked eye within a few hours.

Reversible if the temperature increase is only temporary, this phenomenon can nevertheless lead to the death of the reef.

Reefs also endure a more direct anthropic pressure, far from negligible in certain areas, through numerous pollutions and destructive fishing techniques. Moreover, in less than 20 years, three quarters of the world's population will be settled along coasts. Pressure on this ecosystem is therefore not about to diminish. According to the latest IPCC Special Report published on October 8, 2018, an average global warming of 2 °C would cause a loss of about 99 % of the coral surface (or 70 to 90 % loss in the case of a 1,5 °C warming).

From an ecological point of view, coral reefs' extreme sensitivity to environmental variations unfortunately makes them very good indicators of the Ocean's health. The Pacific is especially interesting to study because it shelters 40 % of the planet's coral, and presents a wide gradient of diversity. The "Coral Triangle" in Southeast Asia is a region where reef biodiversity is at its peak.

Launched in 2016, the Tara Pacific Expedition aims to understand and anticipate the effects of environmental changes on coral reefs at a time of great upheaval.

We intend to inform political decisions, and ultimately change our relationship with the Ocean. *Tara* returned to Lorient in October 2018 after more than 883 days of expedition, having voyaged more than 100,000 km, sampled 32 sites, and accomplished about 2,700 dives. This extraordinary expedition brought back nearly 60,000 samples of corals and also the surrounding seawater so that the microscopic organisms associated with coral can be identified.

The collected samples are now at the Genoscope where they will be carefully studied. Genetic information (the "genome") is located in the DNA, the well-known macromolecule found in all cells of an organism. When the DNA is sequenced, we can see which genes are present by comparing them with a database. Genes carry information: a particular characteristic or trait which, if the gene is expressed, applies to the organism. The samples collected by Tara Pacific provide one of the largest genetic sequencings ever achieved in the environmental field.



## TARA PACIFIC



**After the expedition, the schooner *Tara* returned safely to port. Laboratory work for the Tara Pacific program is now underway...**

**Analyzing the samples will allow us to:**

- 1 • learn about the biodiversity of coral reefs at different levels of complexity, from genome to ecosystem,
- 2 • answer major questions about reef health in the specific context of climate change. Many of the islands or islets explored during the expedition were far from sources of human disturbance and preserved from disruptions directly related to man,

- 3 • explore the capacity of resistance, adaptation and resilience of their habitats to climate change,

- 4 • help develop applications for future medical research. In the months and years to come, the *Tara* database will allow for a thorough study of coral reefs and their ability to adapt to climate change.

This expedition was also an opportunity to observe the Pacific coral reefs along its route, with 70 stopovers in more than 30 countries. The voyage highlighted the disparity in the health of reefs, with major tendencies appearing according to geographical areas. The areas covered by *Tara* on her way through the Pacific Ocean include many reef islands spread over vast territories.

Coral reefs are very diverse. Between Panama and Indonesia, the expedition covered very different ecosystems, responding differently to global and local stresses. Some of these islands are subject to direct and local disturbances, while others are remote from any source of anthropogenic pollution. These different contexts will thus allow us to assess mainly the disturbances resulting from natural modifications of the terrestrial ecosystem. During these two years, the Tara Pacific teams witnessed numerous episodes

of coral bleaching. Linked primarily to warming, this is a process in which heat-stressed corals separate from the beneficial algae (symbiotic micro-algae) that provide them with nutrients.

Certain recent projections show that sometime before 2055, 90 % of the world's coral reefs will undergo severe bleaching every year. The reduction of respite time between bleaching episodes limits the ability of mature corals to fully recover, a process that usually takes 10 to 15 years.

The Tara Pacific data will show which factors favor (or not) the resistance of coral species. These data should make it possible to identify the optimal conditions for ensuring the survival of the corals, taking into account both the environmental parameters, and the biological parameters of the coral and its microbiota. In the coming decades, certain species numerous today will become less prevalent than others. In other words, species abundant today are those for which the conditions are ideal. In the future, the environment will become favorable for the development of other species. This suggests profound changes in coral reefs over the next two decades, causing modifications in the entire food chain and associated ecosystem.

The unique character of this expedition consists in its ecosystemic approach – multidisciplinary and "transversal" – involving coral biologists, geneticists, oceanographers, specialists in plankton and reef fish, bioinformaticians and even medical doctors. This Tara Pacific approach will make available to the international scientific community a unique database on coral reefs, revealing the biodiversity – genomic, genetic, viral or bacterial – of each reef.

By describing the relationships between the various compartments of the reef (coral, microbiome, fish), and particularly in contexts impacted by human activity (pollution, warming, acidification, overfishing, urbanization of the coast, etc.), further research should allow us to obtain important answers for the reefs' future. The great biological and genomic complexity being gradually discovered is expected to provide crucial information for scientists to understand the inner workings of coral reef systems. This also suggests an interesting future for reef conservation.





## AND THE FUTURE...



### ADVOCACY TO SUPPORT RESEARCH

By Romain Troublé, Executive director  
of the Tara Ocean Foundation

**Being at sea, speaking from the sea, understanding the sea with science at the heart of our expeditions – this approach gives us authenticity and ever-increasing international influence.**

This vast ocean, 71 % of the globe's surface, remains to be discovered. Marine research and its current means are far too fragmented, research institutions with real capacity to explore and innovate can be counted on the fingers of one hand. The science of the ocean must enable us to mobilize decision makers.

Since the Rio + 20 Earth Summit in 2012, we have seen a tremendous dynamic among nations recognizing the importance of the ocean for our societies. Sustainable development, climate, oxygen, biological resources, trade, jobs. In many forums, the ocean is at the discussion table, supported by a civil society every day more organized and galvanized by recent victories. But there is so much to do to stir up this dynamic, catch the next wave, find the words to win the public's support and convince everyone that we all have a role to play, no matter how small it is.

The developed countries monopolize access to knowledge about the Ocean. In this unbalanced context, the world must come to an agreement about global governance of this common space.

We are now calling for – and will support – the creation of an international research institute to bring together resources and ideas to meet this challenge. Our elders discovered the Ocean thanks to Commander Cousteau aboard his Calypso.

Let's have an ambitious dream: that the adventures of *Tara* will inspire future generations to care for the sea.

## SPECIAL THANKS



The Tara Ocean Foundation's work is supported by many patrons and loyal partners whom we can never thank enough for their commitment. At all levels, they provide moral, technical, political and financial support for this scientific and human adventure. We are all involved with the Ocean, even in our daily lives.

The entire team wishes to thank our generous donors whose gifts help us advance.

### **The Founders and the entire Tara Ocean Foundation team also want to thank:**

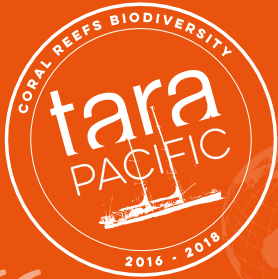
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“

*The Tara Pacific Blue Book invites you on a voyage across the Pacific to explore coral reef archipelagos, meet local populations and learn about conservation projects directly from scientists and local activists. It tells the history and goals of this unique expedition – 2 and a half years crisscrossing the Pacific Ocean to collect samples of the precious corals, today menaced by extinction. Dive into this unique ecosystem, a source of life harbouring 30 % of the ocean’s biodiversity and understand the importance of coral reefs for the planet. Relive this voyage aboard Tara with diverse participants who describe the ecological, scientific, and cultural aspects that made this expedition unique.*

*Have a nice trip!*

”

The Tara Pacific Blue Book was produced with the support of  
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L'ENVIRONNEMENT MONDIAL

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