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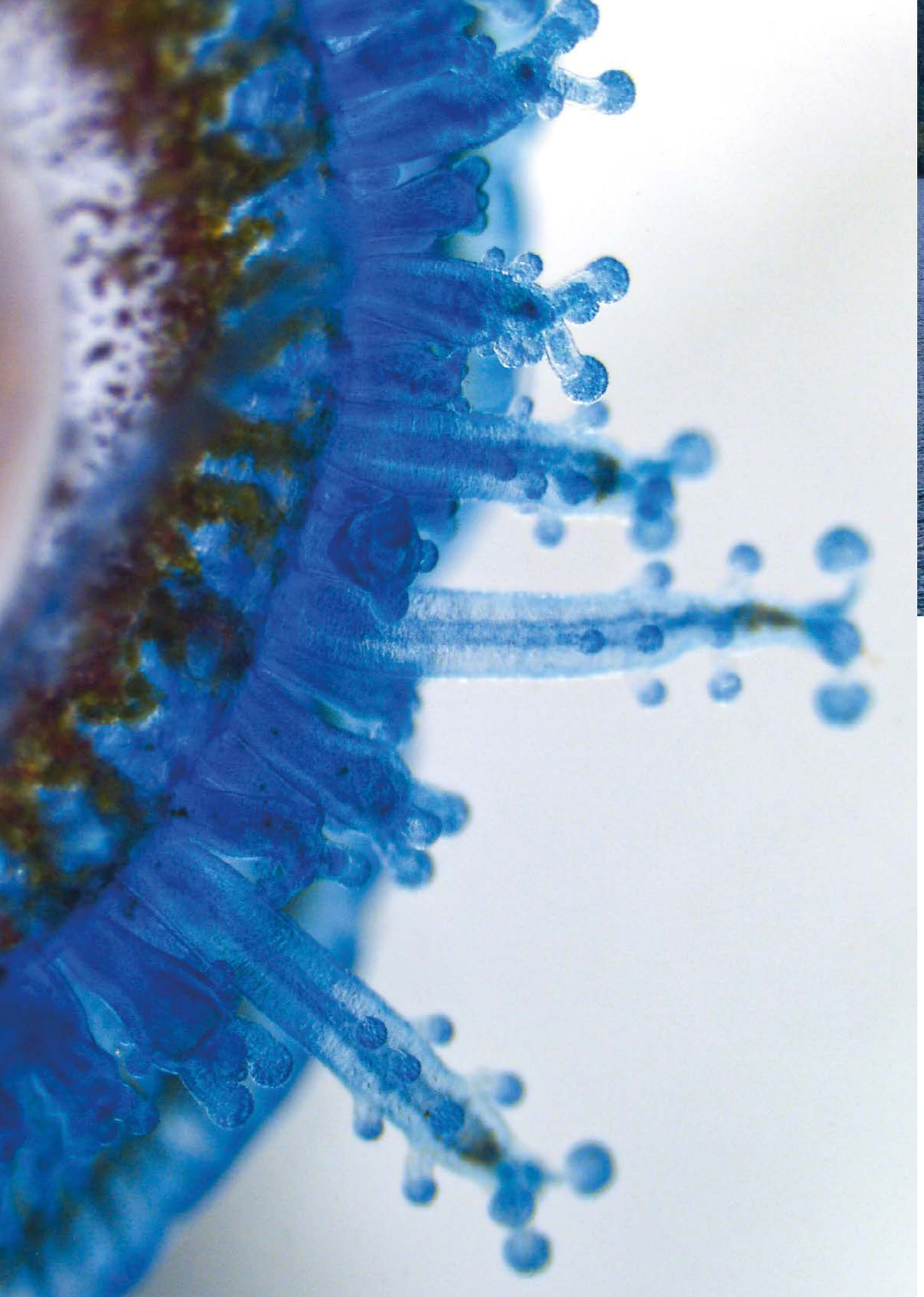
Press kit · End of mission

From December 2020 to October 2022

Mission Microbiomes

Understanding the Ocean's invisible inhabitants to preserve our future

AtlantECO
Atlantic Ecosystems Assessment, Forecasting & Sustainability



The Tara Ocean Foundation is the first public interest foundation in France dedicated to the Ocean. It·s 2 main missions are to explore the Ocean to better understand it and share the relating scientific knowledge to raise citizen and collective awareness. For 19 years, the Foundation has developed a high-level Ocean science in collaboration with international research laboratories of excellence, to explore, understand and anticipate the upheavals related to climate and environmental risks, as well as the impacts of pollution. In order to make the Ocean a common responsibility and to preserve it, the Tara Ocean Foundation also works towards raising public awareness about ocean science and educating the younger generations. By studying and protecting the Ocean, we take care of our planet's global system.

www.fondationtaraocean.org

Right and left : ©Maéva Bardy · Tara Ocean Foundation

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Editorials

Two years ago, almost to the day, in the midst of the Covid-19 crisis, we decided to confirm the departure of the Microbiome mission on December 12, 2020 in agreement with Tara's team, sailors, scientists and the Foundation's board of directors. It was a near-unanimous decision that laid the foundation for this extraordinary mission in many aspects.

First, a departure with only 15 people attending on the quay, without friends, families and local inhabitants usually numerous in wishing Tara's crew fair winds and following seas. It was in fact only a foretaste of the first 6 months of this expedition in Chilean waters. In quarantine, some crew members were not allowed to disembark for 3 months during stopovers. The operations team had to organize hundreds of PCR tests to comply with the rules in force. Sailors and scientists complied with heavy administrative constraints.

Despite this rare adversity, the schooner still traveled more than 70,000 km around Latin America, sailing along Chile, Brazil and Argentina before heading to Antarctica and then the West African coast. The teams on board collected millions of data and nearly 25,000 samples of this invisible marine microbiome, now stored in Tara's holds to be analyzed on land.

The schooner's stopovers and her study of the territorial waters of many countries strengthened relationships with our international partners in these countries. The Tara Microbiome mission hosted many scientists from Chile, Brazil, South Africa and Senegal, among others. In Chile, the CEODOS Chile program, composed of 8 local scientific institutions, will use the data collected on board Tara to: 1) study the status of the carbon pump along the Chilean coast and its role in greenhouse gas exchange, and 2) map the microbial and plankton diversity along the extraordinary environmental gradients characterizing the Chilean coastline. In Brazil and South Africa, the Foundation met AtlantECO's partners, interacted with the program's scientists and formed a new scientific community across the Atlantic Ocean. In Senegal, the schooner's stopover mobilized our partners and led to the implementation of an upcoming 4-year cooperation program with the French Facility for Global Environment.

In Rio de Janeiro last year, when the pandemic crisis finally abated, we were able to share Tara's stopovers again with the public, schoolchildren, scientists, policy makers and the local press. Our embassies and the Foundation's teams mobilized in each country to make these meetings special moments for every participant. The winning artists of the call for projects were also able to join the expedition, almost as originally planned. We were particularly happy to present their work on the occasion of Tara's return.

This expedition of almost 2 years is a global success. However, as in any mission of this magnitude, we had to renounce some of the programme. Thus, we canceled sailing up the Congo River in the Democratic Republic of the Congo for lack of local support. Only the waters flowing into the Ocean were analyzed at the river's mouth. Sao Tome Island's coral reefs, that have never been studied, were also on the agenda but the security situation in the Gulf of Guinea forced us to modify the expedition's route.

We want to pay tribute here to the perseverance, commitment and constancy of our partners and the women and men involved in this extraordinary adventure, aboard Tara as well as on land, thanks to whom the schooner is so proud to return to her home port in Lorient (Brittany).

Étienne Bourgois · President of the Tara Ocean Foundation & **Romain Troublé** · Executive director of the Foundation

Lorient Agglomération shares with Tara a common objective: to work towards protecting the environment on the path of ecological transition. Between 2 missions, the schooner Tara is maintained in Lorient, where she benefits from the know-how of the many local sailing-related companies. The Tara Ocean Foundation's scientific missions are a remarkable showcase for the Agglomeration, the internationally recognized ocean racing center, Lorient La Base, and its network of companies. Tara contributes to making Lorient a city in the world".

Fabrice Loher · President of Lorient Agglomeration, Mayor of Lorient

The Tara Microbiome mission

Key numbers

70 000
kilometers traveled

14
countries visited

270
days of navigation

168
scientific stations

25 000
samples collected

145
persons embarked

30
crew rotations

30
technical and awareness-raising stopovers

6 480
hours spent on shifts

For 22 months, the schooner Tara sailed 70,000 kilometers across the South Atlantic Ocean, along the coasts of South America and Africa, down to Antarctica. At the initiative of the Tara Ocean Foundation, the European program AtlantECO, the scientific consortium CEODOS Chile and scientific partners from more than 15 countries, the Tara Microbiome mission involves 65 research institutes worldwide to study the marine microbiome and its interactions with the climate and chemical and plasticpollution.

Marine micro-organisms play a key role in the Ocean, since they account for about two-thirds of marine biomass, as well as most of the world's biodiversity. They are the first link in a huge network of living beings that feeds a large part of humanity. True ecological and economic service providers, these marine organisms, invisible to the naked eye, capture as much carbon emissions generated by human activities as terrestrial plants. Though it is a key part of the climate machine, the functioning and dynamics of this invisible world remain largely unknown today.

Organizing a scientific and human expedition

During this mission, the schooner Tara made more than 20 ports of call in 12 countries (Chile, Panama, Martinique, Brazil, Argentina, Antarctica, South Africa, Namibia, Angola, Congo, Gambia, Senegal, Portugal). Before each stopover, the logistics team on shore prepared everything so that the arrival of the schooner was as smooth as possible, in terms of relationships with port and local authorities, customs in the case of import or export of equipment, immigration services and the French Embassy in each of the countries coordinated. On the scientific level, in order to sample in a country's exclusive economic zone (EEZ), it was necessary to apply for a research permit several months before Tara's arrival in the host country.

Each stopover is an opportunity to supply the schooner with different needs :

- The on board cook must draw up an inventory of food stocks and replenish supplies to ensure the next long periods at sea.
- *Tara,* like any sailboat, suffers wear and tear and requires constant maintenance. The on board crew, in coordination with the shore team, constantly assesses the schooner's needs in terms of technical equipment to anticipate orders with our suppliers in France.
- Finally, the samples collected during the mission are temporarily kept aboard the schooner before being sent to our various partner laboratories. Depending on the type of sample, preservation differs and some requires liquid nitrogen storage.

The scientific consortium (grouping of laboratories and institutions involved in the mission) and collaboration between scientists do not end with the expedition. Indeed, after collecting samples in the waters of all these countries, we must first report to our local collaborators on the work carried out and share with them the results of our research by sending reports on each leg, supplemented by environmental and contextual data files. In the second phase (at least as long as the expedition), scientists must exploit and present their results in articles to be published in various scientific journals. To make possible for scientists to collect samples aboard the schooner, a team of sailors took turns throughout the mission to maneuver Tara. These 6 men and women are present on board at all times. Aboard Tara, science isn't on one side and navigation on the other. Everyone collaborates to apply, as best they can, scientific programs to the field reality: that is to say, an ocean is sometimes capricious and unpredictable and requires a high capacity for adaptation and great reactivity. We don't work against the Ocean, but with it. That's why sailors are essential to assist scientists to better understand winds, tides, swells and storms. Hoisting sails, preparing scientific stations, launching scientific tools, but also feeding the crew and ensuring the technical maintenance of the schooner : Tara's crew is crucial to the smooth running of the mission.

A fleet dedicated to the study of the Ocean

The Tara Microbiome mission is an integral part of the international AtlantECO program funded by the European Commission. This program brings together more than 36 scientific institutions in Europe, Brazil and South Africa. This international scientific collaboration aims to develop a thorough understanding of the issues related to the Atlantic Ocean and assess its health status. *Tara* is one of the 6 vessels composing this oceanographic fleet dedicated to the study of the Atlantic Ocean. As the first ship to launch, protocols were tested and developed aboard the schooner in order to be reproduced on all other research vessels. During these expeditions, scientists will study the marine microbiome's functioning and dynamics, and analyze the impact of plastic and chemical pollution and environmental changes on these microorganisms.

Overview of the project

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Mission Microbiomes

OCEAN CURRENTS

How does climate change disrupt ocean currents and microbiome distribution?

1 • Chilean coasts: low oxygen zone (anoxic)

2 • Guyana-Amazon: area of connection and exchange between two ocean basins influenced by the Amazon River

3 • Weddell Sea: a key region for the climate, where deep, cold currents are formed

4 • Chile and Africa: deep water upwellings, very rich in nutrients essential for fish stocks and the carbon pump

FERTILIZATION & POLLUTION

How does the land fertilize the Ocean, and what are the impacts of microplastic pollution on the microbiome?

5 • Chilean coasts: influence of fresh water from terrestrial glaciers

6 • Major rivers (Amazon, Orange, Congo, Gambie and Casamance): study of ocean plumes

SMALL-SCALE PHENOMENA

How do temporary eddies and small currents change large-scale models?

7 • Atlantic Ocean: study of movements of the microbiome under the action of eddies.

Nutrient-rich upwelling areas

CEO DOS Chile

AtlantECO
Atlantic Ecosystems Assessment, Forecasting & Sustainability

Major scientific questions

The impact of massive nutrient supply from rivers on the microbiome's functioning

• Rivers drain continents and therefore contain a large amount of nutrients. How does this nutrient supply impact the microbiome's productivity and the carbon pump?

• Rivers are true sentinels of the ecological state of watersheds. These regions are largely unknown to international research. Are the services provided by the microbiome impacted by the influence of rivers?

The importance of species interactions on the life and death of the marine microbiome

• The Ocean hosts algal blooms so massive that they are visible from space and play a fundamental role in the functioning of the marine ecosystem.

• How do these interactions between species, such as viral infection, predation or symbiosis, impact bloom dynamics?

The importance of the microbiome on the biological carbon pump (Weddell Sea)

• The Weddell Sea is an important downwelling site (convergence and sinking of surface waters towards the ocean floor). What structure of the local microbiome is responsible for this major carbon flux? How and to which extent this microbiome is impacted by the presence of icebergs, increasingly common in the region and inducing changes in the physical and chemical composition of seawater?

The impact of ocean circulation and currents on the microbiome's functioning

• Upwelling: A region that is extremely rich in plankton biomass and highly productive in terms of fishing. These cold water currents, enriched with nutrients, rising to the surface are generated by strong winds that expel hot surface water. These winds are affected by climate change. How does the microbiome support this productivity? How do scientists predict the development of this process in response to deoxygenation and climate change?

• Turbulence: How do ocean eddies modulate the production of biomass? How do they regulate the patch structure in living organisms?

The impact of plastic and chemical pollution on the ecosystem services provided by the microbiome

• Plastic pollution was studied along the Brazilian coast according to the following protocol: samples were collected upstream and downstream of cities to understand their role in the flows and typology of plastic pollution, and how this pollution affects microorganisms in the water column.

The Tara Microbiome mission step by step

Chile

The first stage of the Tara Microbiome mission was carried out in Chile in close collaboration with the consortium CEODOS Chile, a scientific program resulting from a Franco-Chilean cooperation started in 2015. The schooner Tara sailed up the Chilean coast from Punta Arenas in February 2021 to Iquique in May 2021.

Scientists on board *Tara*
Milena Cerda, Céline Dimier, Rodrigo Torres, Douglas Couet, Miguel Moll, Emilio Alarcon, Eric Pelletier, Josep Erta, C amila Fernández.

Preliminary observations

• This first part of the Microbiome mission has already shown that the dead zone (ocean area highly depleted in oxygen) previously documented to the north and south of Chile actually extends all along the coast.

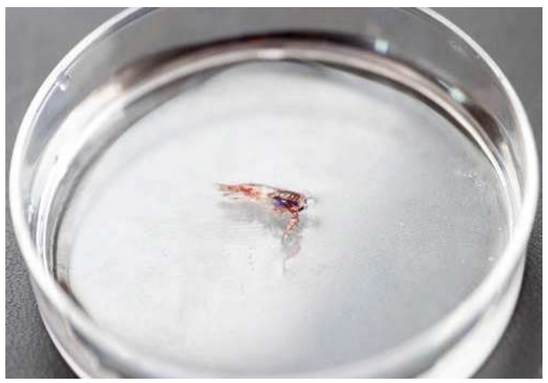
• We found that microplastics are present everywhere, but they are widely concentrated near populated areas. We can no longer consider pristine areas as « virgin ».

• We have also confirmed that the Chilean coast is extremely active in its ability to deal with greenhouse gases.

For more than 4 months, a complete sampling was carried out (4 phases, 36 sampling stations, more than 5,000 samples of seawater collected at various depths, down to 1,000 m) between Punta Arenas and Iquique to establish, for the first time, a complete diagnosis of the plankton health status along the Chilean coast. The 4,500 km ranging from the south to the north of the Chilean territorial sea are considered a true natural laboratory for studying the effects of climate change. The objective is to understand the impacts of climate change on the marine microbiome, assess the intensity with which the carbon pump operates in this zone, acquire additional data on microplastics in salmon farming areas and the Patagonian Fjords, and explore the growing influence of large oxygen- deficient zones.

« This mission has just launched the CEODOS Chile program, a long-term initiative aiming at monitoring the Chilean coastal waters every 5 years to regularly update a global diagnosis related to climate change. » explains Camila Fernandez, a CNRS researcher, coordinator of the Microbiome mission in Chile and visiting professor at the Oceanography Department of the University of Concepción.

Tara's visit in Chile reinforces a scientific cooperation initiated in 2015 with the funding of 2 Chilean postdoctoral fellowships by the Tara Ocean Foundation and the French Facility for Global Environment. « It's also a structuring element for Chile that allows to implement a multidisciplinary scientific project and consolidate its recognition on the international stage », says Alejandro Maass, director of the Mathematical Modeling Center at the University of Chile and codirector of the CEODOS Chile program.



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Brazil

Brazil is a country with a wide variety of ecosystems and rich biodiversity. Its territory is covered by the world's largest tropical forest and crossed by the world's largest river, the Amazon. These 2 key elements make Brazil a focus country in regards to research on climate change. The schooner Tara studied the Brazilian waters between September and November 2021.

Scientists on board *Tara*
Natalia Torres, Nils Haentjens, Stéphane Pesant, Léa Olivier, Josep Erta, Paula Huber, Andréa Freire, Douglas Couet, Xiomara Franchesca Garcia Diaz, Helena Carvalho, Ali Chase, Alessandra Gomes, Pedro Junger, Erica Becker, Samuel Chaffron, Thomas Linkowsky, Lee Karp-Boss, Emmanuel Boss, Hugo Sarmento, Gleice de Souza Santos, Andrea Green

Preliminary observations

• Ocean warming and deforestation affect the water cycle: "flying rivers" - movements of large quantities of water vapor transported in the atmosphere from the Amazon Basin to other parts of South America - transform and influence the flows of water, nutrients and carbon entering the Atlantic Ocean.

• Micro- and macroplastics are found almost everywhere, even in the Amazon rainforest, one of the largest standing forests in the world.

• The Vitoria-Trindade seamount chain is a biodiversity hotspot for macro-organisms. Our expedition explored the microbial diversity of this important region, where new species and genes are expected to be discovered.

• The waters of the Amazon River have a huge impact on the Atlantic Ocean's circulation and biology: they form a physical barrier for the larvae dispersion of coastal species. Moreover, very specific microbial species bloom where fresh waters, rich in nutrients, mix with the Atlantic Ocean, about 300 km off the coast.

The Amazon plume

Northern Brazil is characterized by the presence of an intense ocean current. This current and the huge eddies (up to 300 km in diameter) it generates carry the river waters towards the Caribbean Sea and spread them over a large area, thus diffusing nutrients, pollutants, but also the microbiome trapped in these eddies. The schooner Tara sailed from Martinique (France) to the Brazilian coast to study this phenomenon. To understand the impact of the Amazon River on the Atlantic Ocean, the scientific team sampled the Amazon plume, created by the mixing of waters from the Amazon River and the Atlantic Ocean. The river discharges 200 million liters per second on average into the ocean. This freshwater, warmer than seawater, is at the origin of a highly dynamic surface plume that affects the tropical Atlantic Ocean's salinity and temperature.

Plastic pollution in the Amazon River

The schooner Tara sailed to the heart of the Amazon River. The scientific team analyzed the content of microplastics and nanoplastics in the water. The Amazon River drains 40% of South America and therefore carries a lot of plastic and chemical pollution. Samples were collected upstream and downstream of cities to understand their impact on plastic pollution.

The Vitória-Trindade seamount chain

Tara's scientific team analyzed the biodiversity of a submarine volcanic chain between Salvador de Bahia and Rio de Janeiro in Brazil. This underwater mountain range, called Vitória-Trindade, is located in the part of the Atlantic Ocean most depleted in nutrients. The topography generates frequent upwellings that enrich the water column in nutrients. This area thus constitutes a biodiversity hotspot and hosts many coral reefs. Scientists carried out day stations, and also for the first time at night:

« Many of these small organisms move upwards overnight, thus leading to the largest animal migration on Earth ! Our second objective was therefore to collect biological samples at night to better understand this daily variation. » say Pedro Junger and Erica Becker.

It will also allow bioprospecting for chemistry or pharmacology. During her study of Brazilian waters, the schooner welcomed on board scientists from partner institutions : the Federal University of São Carlos, the University of São Paulo and the Federal University of Santa Catarina. The Tara Microbiome mission and the AtlantECO project structured a long-term collaboration between the Tara Ocean Foundation and Brazilian research institutions that are partners in the project. Beyond the purely scientific aspects, the schooner's 5 stopovers in Brazil in 2021 created human ties with young people, teachers, association leaders and local policy makers. Tara's journeys in Brazil were also an opportunity to embark junior researchers during legs, creating a whole generation of Brazilian Taranauts who dream of returning on board !

Argentina

Every year in the spring, massive blooms of coccolithophores occur around the world, linked to increased light and stratification of the water column. Coccolithophores are micro-algae that capture CO_2, produce oxygen and are covered with small calcareous plates made inside the cell. One of the most important blooms is along the east coast of Argentina, between Buenos Aires and Ushuaia, which scientists studied during the Gayoso expedition in December 2021.

Scientists on board *Tara*
Flora Vincent, Michel Flores, Constanze Kuhlisch, Morgane Ratin, Guillaume Bourdin

Preliminary observations

• We detected a very beautiful bloom of coccolithophores thanks to satellite imaging, and conducted a Lagrangian approach which consists in following the same mass of water for several consecutive days using floats - an approach carried out for the first time in this region, to our knowledge. We have unique data that make the link between what happens in water and what we see from space, thus allowing us to integrate biological phenomena across large spatial scales.

• We carried out 12 stations (i.e., an average of one every two days), and were able to deploy innovative protocols on board (predation and RNA sequencing on a single cell) which will complement the suite of ecosystem data collected during the entire Microbiome Mission.

• We observed several phenomena of massive proliferation: coccolithophores, but also diatoms and dinoflagellates. Regarding the coccolithophores, the bloom started later than in 2020 and further south, but it's difficult to say if this is due to climate change. The diatom bloom was particularly important this year, and led to the presence of many illegal fishing boats which came for the cuttlefish that benefit from this bloom. Regarding the dinoflagellate bloom, our Argentinian partners expressed a keen interest because it involves a little-known species.

During this mission, Tara studied a bloom of coccolithophores between Buenos Aires and Ushuaïa (Argentina) in collaboration with the Argentinian research vessel, Bernardo Houssay. This massive bloom of microscopic algae takes place every year, in December, when the right environmental conditions occur. Coccolithophores - a variety of micro-organism at the origin of these blooms - are studied because they are capable of photosynthesis (i.e., using the sun's energy to produce oxygen and absorb carbon dioxide) and are the base of the food chain. These micro-algae are at the center of a large network of interactions that determine their survival and death: viral infections, predation, cooperation. Studying these interactions in the natural environment can give us the keys to the mechanisms at work behind these monumental phenomena of blooms which remain poorly understood.

This study will advance the understanding of the blooms, in particular thanks to state-of-the-art techniques never before deployed in these waters, and so-called "drift" approaches that follow the blooms from start to finish. The schooner was able to track this phenomenon thanks to data obtained in real time, in order to sample as closely as possible. The scientific team followed in the footsteps of the Argentinian scientist Ana Maria Gayoso who was the first to observe the strong presence in this region of the algae Emiliania huxleyi. The scientific research vessel of the Argentine Naval Prefecture, the Bernardo Houssay, was the second half of this Gayoso expedition. By taking the inverse of Tara's route a few days before the passage of the schooner, it was able to study the first phases of this bloom. The two boats came together in Buenos Aires to present their research.

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Antarctica

Covered in ice, the Antarctic continent is located at the South Pole. It is bordered by the Southern Ocean and the Ross and Weddell Seas. More than 700 kilometers from the American continent, the Antarctic Peninsula is an isolated area. Most of the world's ice is contained within the Antarctic continent. Formation and disappearance of ice makes the continent accessible for only 2 to 3 months - during the summer period (January-February). Tara arrived in the \Weddell Sea in January 2022, and scientists aboard studied the microbiome through February.

Scientists on board *Tara*
Alessandro Tagliabue, Léa Olivier, Natassia Patin, Chris Bowler, Douglas Couet, Thomas Linkowski

Preliminary observations

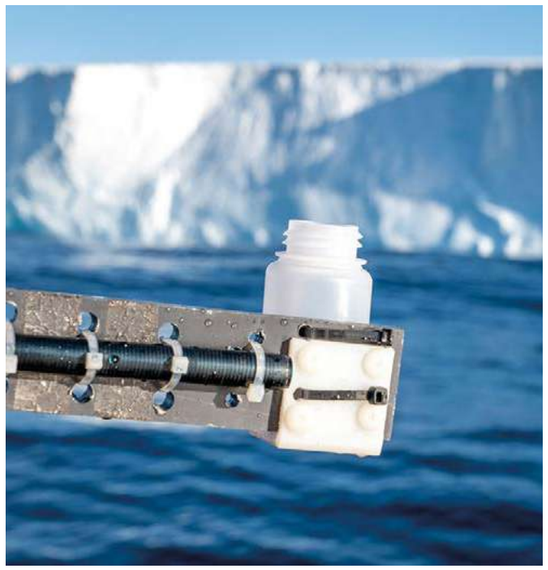
• Tara pushed her limits by traveling as far south as possible, into the deep waters of the Weddell Sea, documenting for the first time the impact of large-scale gradients of Antarctic conditions on the microbiome. A new collaboration with the German icebreaker Polarstern extended our sampling to larger spatial and temporal scales.

• Tara sampled during a record-breaking decrease of ice in the Weddell Sea, an exercise that could eventually be used to predict the future of the region.

At the entrance to Drake Passage separating Antarctica from South America, the Antarctic Circumpolar Current established itself in the Southern Ocean about 20-40 million years ago. Gradually, the microorganisms in Antarctica were isolated from other species present on the globe. To better understand Antarctica's particular microbiome and its link with the carbon pump, Tara sampled these waters at the beginning of 2022.

The program included studying an iceberg called "Tasmania" which measures 22 meters high and 0.6 km2 in area. The study was conducted on the iceberg during a 30-nautical-mile drift to understand its impact on the microbiome. Scientists aboard Tara collected samples from 10 to 1,000 meters deep to explore and understand changes over time through the interpretation of cores and sediments collected by geologists in the area.

A continent of peace and scientific research, Antarctica has long been the greatest success story of international cooperation for conservation of the marine environment. However, for more than 5 years, the diplomatic situation has been blocked. Global warming, pressure for fishing rights, and the development of tourism in the region greatly threaten the stability of the Antarctic ecosystem, a veritable thermostat of the global climate. Added to these current challenges is the prospect of lifting the ban - in 2048 - on the exploitation of mining resources, slowly transforming Antarctica from a sanctuary to a potential land of exploitation. The importance of these ecosystems for the regulation of the climate and life on Earth is global and requires that States relaunch the collective momentum of cooperation at the origin of the Antarctic Treaty and the Protocol of Madrid.
We are just beginning to see how the microbiome works, but Tara's studies in Antarctica during the recent mission will certainly contribute to the international effort for the conservation of the Southern Ocean and will be used to understand how species endemic to Antarctica have evolved and adapted to this extreme environment. In a way, Antarctica is a mirror of the phenomena that affect the entire world Ocean. Observation and data collection allow scientists to propose models of climate change and warn of future changes. The Microbiome mission in 2022 was the 5th expedition to Antarctica led by the Tara Ocean Foundation.



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Transatlantic

The Ocean has a significant number of vortices caused by pressure differences that create ocean currents. Under the effect of the Earth's rotation, these currents reach an equilibrium by rotating around the center on scales of 10 to 200-300 km. Thus, like atmospheric storms, the eddies' currents revolve around their center, allowing them to move in the Ocean for several weeks or even several years. Each whirlpool has a particular "signature" depending on its properties, i.e., temperature and salinity. 2 types of large structures can be distinguished: the anticyclone, and its opposite, the cyclone. Through their ability to transport masses of water, as well as their impact on other parts of the climatic reservoir such as the atmosphere or the biosphere, oceanic eddies are essential in the dynamics of the ocean. On a smaller scale, oceanic fronts, which separate two parts of the ocean with different physico-chemical properties, are also of great interest. They mark the separation between, for example, the whirlpool and the environment where it is moving and can also mark the demarcation between two oceans. These very dynamic zones, where many mixtures take place, have a very important role on biological communities. During Tara's transatlantic voyage between South America and Africa, the scientific team on board studied physical phenomena in particular eddies and ocean fronts, to understand their impact on the microbiome. Crossing the Atlantic lasted 49 days, from March to April 2022.

Scientists aboard *Tara*
Rémi Laxenaire, Giancarlo Bachi, Cora Höerstmann, Paula Huber, Alison Chase, Clara Trellu

Preliminary observations

• Sampling of a cyclonic eddy in the rich waters of South Georgia was found (several months after its formation) to be associated with a strong bloom of diatoms, even though this eddy was detached from the surface.

• A very intense front, marking the separation of the Atlantic and Southern Oceans, was found to be composed of numerous filaments, with indications on the surface of planktonic communities resulting from the mixing between these oceans. This observation requires confirmation by genetic analysis.

The transatlantic is a period of navigation that allows the boat's planned route to be significantly modified in order to follow particular water masses. Since the ocean is a rapidly changing environment, these dynamic structures are ephemeral. Rémi Laxenaire, chief scientist of this leg, had to adapt in real time aboard *Tara* :

« My role was to analyze in real time the satellite images as well as the measurements observed aboard the schooner in order to gradually define the sampling plan. Thus, through meetings with the scientists on board, and in consultation with the sailors, we defined together what we were going to do in the coming days. »

Thanks to these satellite images analyzed daily on board, the scientists therefore identified different oceanic structures (eddies and fronts) which they then targeted for sampling aboard Tara. The goal is to study the link that exists between these dynamic structures visible by satellite, and the entanglement of biological communities that only on-site sampling can characterize.

The scientific team relied on scientific studies which suggested that an eddy characterized by stable hydrological conditions (temperature, salinity) would be composed of a low diversity of organisms. Indeed, the marine species best adapted to the environment should develop more, causing a loss of biodiversity. On the contrary, the « front type » structures are zones of exchange where the physico-chemical and biological properties evolve rapidly, not allowing communities to dominate, so the diversity of the communities should be greater. The scientists thus wanted to verify that plankton diversity is greater at the level of the fronts than in the centers of the oceanic eddies. Finally, the scientific team aimed to use new methods for analyzing biological communities by studying the proteins created by these organisms, to highlight changes in the behavior of plankton depending on the rapid changes in physicochemical properties at oceanic fronts.

South Africa, Namibia, Angola

The Benguela Current flows from South Africa to the coasts of Namibia and Angola. To the south, the waters of the Atlantic mix with those of the Indian Ocean, causing multiple whirlpools that reach as far as Brazil. The ascent of the Benguela Current was carried out between April and June 2022.

Scientists on board *Tara*
Emma Rocke, Nicole Dames, Ndamononghenda MATEUS, Mathilde Bourreau, Céline Dimier, Thomas Leeuw.

Preliminary observations

• Overall, our first observations of the Benguela upwelling confirmed its reputation as one of the most productive areas in the world.

• Oxygen-deficient areas extended beyond the edge of the continental shelf into Namibian waters. This phenomenon has occurred in the past, but it signals a possible change in the oxygen dynamics in this region.

• Our onboard microscope observations revealed markedly different plankton communities as we sampled further north in Namibia. Extremely large diatom cells (nearly 1 mm in diameter) were observed, confirming enormous productivity (and therefore high carbon sequestration) in these areas.

• In addition to the TARA protocols, we measured primary production and nutrient uptake rates at coastal stations off Namibia. This will help us quantify the fertility of the ocean there, i.e. how much carbon in the form of phytoplankton it can produce at any given time.

Along the coasts of West Africa from South Africa to Angola, cold waters rising from the depths, also called upwellings, bring nutrients to the surface. Due to prevailing winds that “push” surface water, this allows cold, deep, nutrient-rich water to rise to the surface. These waters feed the proliferation of phytoplankton, which provides oxygen to the atmosphere, absorbs CO2 and provides essential organic matter to feed the bottom of the food chain. Very productive in terms of fish because it is very rich in nutrients, the Benguela Current has a rich and varied ecosystem. It has considerable influence over the South Atlantic Ocean. Previous studies suggest that the availability of certain nutrients in the ocean can directly influence the microbiome. These differences can result in changes in the ecosystem services provided by the microorganisms. For example, these waters feed the proliferation of phytoplankton, which itself provides oxygen to the atmosphere, absorbs CO2 and produces essential organic matter to supply the bottom of the food chain as explained above.

However, scientists do not have a complete understanding of the interactions between the microbiome and its environment. To add even more complexity, they have little knowledge of the composition and diversity of the microbiome in the Atlantic Ocean and on the west coast of Africa. Scientists therefore want to understand the biogeography of the marine microbiome on African coasts and how it evolves according to various environmental factors. They will carry out sampling to study microorganisms and environmental variables in order to shed light on the co-limitation of nutrients in the South Atlantic.

«We need to understand the role microbes play in these systems so that we can build models that can predict how things will change under climate change scenarios. These systems also contain areas of low oxygen content which produce powerful greenhouse gases. We need to better understand the causes of this phenomenon in order to take measures to slow it down.»

Emma Rocke, chief scientist aboard Tara. The data compiled from this exercise will be compared with the data collected in 2020 in Chile, a country which is at the same latitude and also experiences upwelling phenomena.

During the Foundation’s stopover in Cape Town, South Africa, the schooner Tara welcomed on board 17 students from 10 countries (South Africa, Ghana, Cabo Verde, Benin, Kenya, Namibia, Angola, Cameroon, Ivory Coast, Guinea) as part of the AtlantE-CO training course in order to teach them the scientific protocols implemented on board. Two of the students present during the day then boarded the ship as part of the scientific team between Namibia and the Republic of Congo.

Furthermore, the stopover in Cape Town was also an opportunity for the Tara Ocean Foundation teams to meet their South African partners, members of AtlantECO from the University of Cape Town, CSIR and the University of Pretoria.

Republic of Congo, Gambia, Senegal

Sailing up the West African coast, the schooner studied the impact of rivers when they flow into the Atlantic Ocean. Scientists studied the Orange River and Congo River plumes, and traveled up the Gambia and Casamance Rivers in order to measure the presence of plastics along these rivers, but also to measure their impacts on microbial communities. By sampling off Senegal on the continental shelf, a very productive area for fishing where an upwelling phenomenon is observed in winter, scientists will be able to characterize the planktonic communities present upstream of the phenomenon which will be sampled in December by an IRD campaign in collaboration with IFREMER.

Scientists on board *Tara*
Jean-François Ghiglione, Anne-Leila Meistertzheim, Edouard Lavergne, Karine Lebaron, David Leistenschneider, Miléna Cerda, Noé, Timothée Brochier, Josep Maria Herta Montejo, Ange Diedhiou, Muguette Allegre, Erica Becker, Pedro Junger, Samuel Chaffron, Suzana Nicolau, Thulani Makhakanyane, Charlotte Begouen Demeaux, Mancha Mabaso, Douglas Couet, Guillaume Bourdin, Éric Pelletier, Louis Caray, Damaria Ardène Boussiengue, Antonella Ruggiero, Charlotte Begouen Demeaux.

Preliminary observations

• Our first observations from river samplings showed very localized and very dense pollution close to the villages along the river.

• Sampling in rivers revealed a high presence of macroplastic, but a fairly low presence of microplastic.

• Sampling off the Senegal coast revealed high productivity and high plankton biomass outside the upwelling phenomenon, but also the presence of minimum oxygen at a depth of about 90 meters.

Tara traces the source of plastic pollution on the West African coast

Sailing up several rivers in Africa (Gambia and Casamance), the Microbiome Mission continued its exploration of plastic pollution, until now carried out mainly at sea. Are the rivers of Africa more polluted by plastic waste than European rivers? What is the influence of the tide, salinity, and human activities on the distribution of macro-, meso-, and micro-plastics along the rivers? How do microorganisms adapt to the omnipresence of microplastics in their ecosystem? In August and September 2022, samples at sea and in the estuary were collected aboard the schooner Tara, then from light boats, where going from land to bridges was necessary to reach fresh water. In mangroves and rice fields, our first observations showed very localized and dense pollution near the villages bordering the river, with types of plastic different from the single-use plastic generally found in Europe: fishing nets and textile products, and a small quantity of flexible packaging from food and drinks. In river water, we found fewer microplastics (<5mm) than in Europe, except in proximity to the large cities near estuaries. A very fine characterization of the chemical composition of these plastics will be carried out from the dozens of samples collected in the water and along river banks. Analysis of the life on these plastics will also identify any pathogenic microorganisms transported from the river to the sea by these plastic «rafts» which then disperse into the Atlantic Ocean. This work follows our expeditions dedicated to studying the plastic cycle in rivers and the Ocean (Tara Mediterranean and Microplastics 2019) and is linked to the participatory science campaign «Plastic under the Magnifying Glass» organized by the Tara Ocean Foundation.

The Gambia River

Objectives of the Gambia River cruise: to observe changes in microbial life across the continuum river-sea and also to assess plastic pollution in the river, including its relationship with microbes. The research vessel Tara sampled several rivers in South America (including the Amazon) and West Africa during the Microbiome project, making it possible to assess the microbiomes and the connectivity of plastic between rivers and the Atlantic Ocean. We found so much debris at the sampling site on the river bank near the city of Tendeba that we stopped sorting the debris (about 15 kg) after only a 10-meter transect for the protocol OSPÄR (instead of the usual 100-meter transect). Trash consisted of a lot of clothes, ropes and fishing nets. Quick observation showed little macroplastic pollution in the mangrove, which covered most of the the sampling area (from Banjul to Kauur). Interestingly, we found relatively few microplastics when sampling in the river with a Manta net. Additional analyzes by partners of the Microbiome project are needed to assess how plastic pollution is related to transporting invasive or pathogenic species in the Gambia River and in the Atlantic Sea. The relationship between plastic pollution and the dynamics of environmental parameters along the river-sea continuum (salinity, nutrients, biogeochemistry,...) as well as the microbial life in surrounding waters will be also studied.

The Casamance River

The objectives of the cruise on the Casamance River in Senegal were to observe changes in microbial life in the river-sea continuum, and to assess the river's plastic pollution in relation to the sea. The Ziguinchor bridge over the Casamance River did not allow the schooner Tara to go further along the river, so the scientists used 2 zodiacs to reach the sampling stations. As in the Gambia River, we found so much debris at the Nikine beach sampling site and on the bank of the Karabane River that we stopped sorting debris (about 20 kg) after only 25 meters. It's interesting to note that we found relatively few microplastics when sampling in the river with a manta net. We observed major pollution by macroplastic debris localized near cities with little extension to the river, and relatively low microplastic pollution in the Casamance River.

The upwelling zone off Senegal

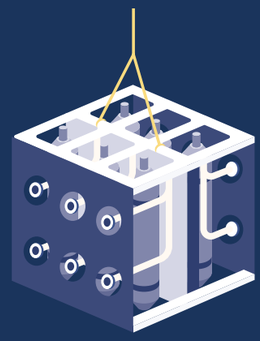
During the leg between Banjul and Dakar, scientists sampled the upwelling zone off Senegal as part of a collaboration with the IRD, which regularly studies this highly productive area supporting the local fishing economy. Several sampling stations were carried out along transects from the coast out to sea during the pre-upwelling season (July/August) in order to study the communities present before the upwelling season (December/January). The IRD campaign will complement Tara's sampling at the same stations, integrating the omics protocols of the Microbiome Mission. This sampling had two main objectives: to characterize the state of the marine microbiome in the «pre-upwelling» period, but also to characterize the OMZ (minimum oxygen zone) (~100m) encountered in this area off the coast of Senegal. Several of these areas of minimum oxygen were sampled by Tara during the mission off South Africa and Namibia, and also under the Guinea dome. This close collaboration with the IRD will provide a better understanding of the evolution of the plankton communities supporting fish stocks in the region, before and during upwelling periods, and will also allow us to study their evolution under the expansion of OMZs which can impact these communities.

Photos 1 and 2 : ©Maxime Horlaville • Tara Ocean Foundation et photos 3 and 4 : ©Maéva Bardy • Tara Ocean Foundation

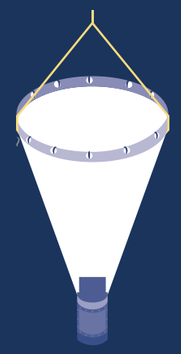
Tara, a floating laboratory

Tools for sampling

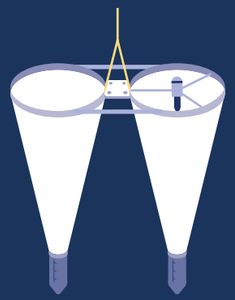
CTD rosette



Geotrace rosette



le deck net



Regent net

Manta net

Dekati
(particle-size spectrometer)

la bow pole

5 types of nets with different mesh sizes are used to capture various species. To study the composition of the water column, these nets are deployed at a depth of 200 meters and brought up to the surface, capturing the organisms along the way.

- 20 micron (phytoplankton)
- 200 micron (zooplancton)
- 680 micron (fish larvae & small fish)
- 330 microns Manta net (used primarily for collecting plastic on the surface)
- 5 micron net on deck (to filter water from the rosette)

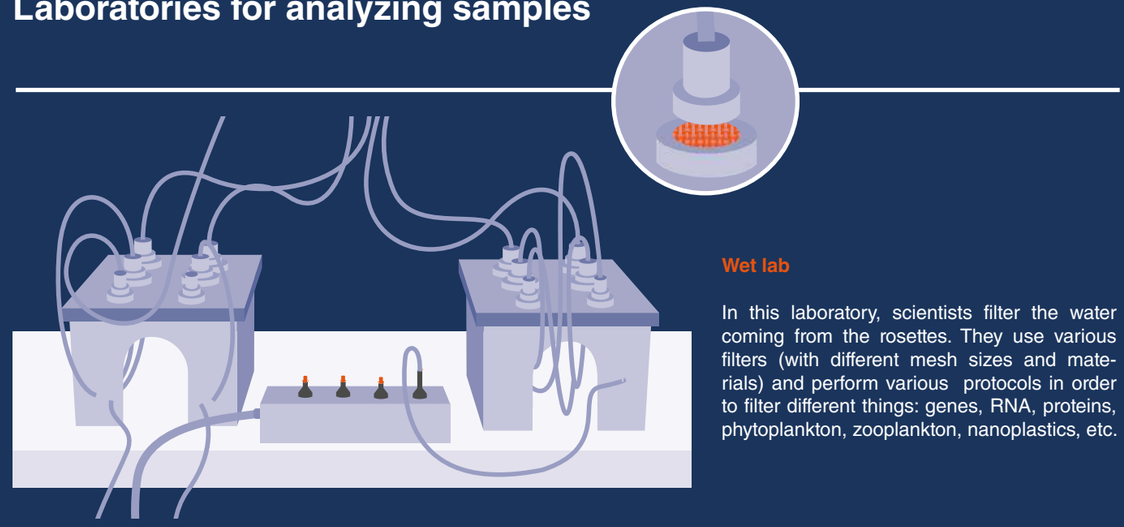
The 2 rosettes can be deployed to a depth of 1,000 meters. Thanks to their Niskin bottles, they collect samples at various depths to characterize the water column. In addition to sampling, the CTD rosette has many sensors that record salinity, temperature, and oxygen levels.

The bow pole analyzes trace metals in the atmosphere and in the water.

The air pump captures aerosols using filters that are changed 3 times per day.

The Dekati continuously analyses the air and aerosols.

Laboratories for analyzing samples



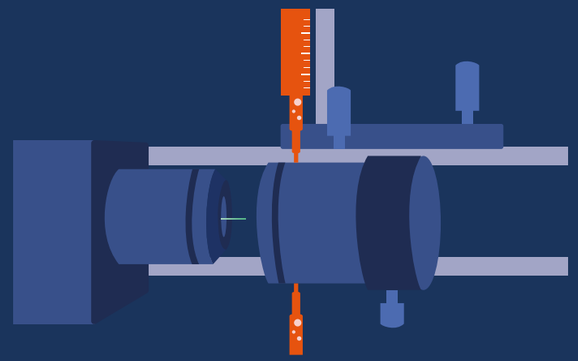
Wet lab

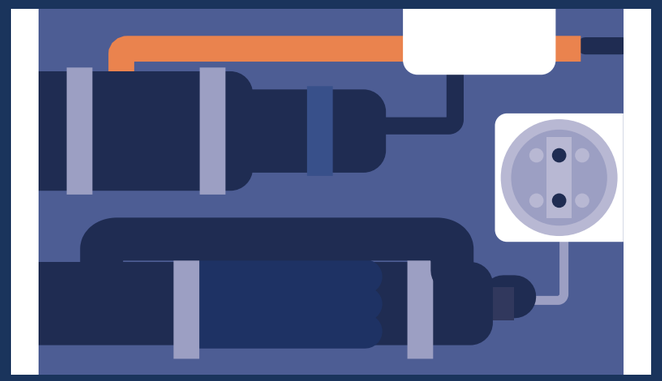
In this laboratory, scientists filter the water coming from the rosettes. They use various filters (with different mesh sizes and materials) and perform various protocols in order to filter different things: genes, RNA, proteins, phytoplankton, zooplankton, nanoplastics, etc.

Sorting lab

In this laboratory, researchers sort the collected samples and inventory the various species present, as well as the pollutants.

- **Flow cam :** This instrument takes images of plankton. When a sample from a net passes through the flow cam, all the organisms present are photographed. This allows scientists to establish inventories of the species present in each region.
- **Magnifying glasses :** used for sorting plastics by hand.
- **Filtration :** Everything from the nets is filtered.





Underway lab

In the Underway lab, a pump brings in water continuously from underneath the boat. It passes through a circuit comprised of up to 6 instruments for studying water:
SeaBird Scientific TSG : measures temperature and salinity
Optical instruments :
ACS : measures the concentration of chlorophyll and the average size of particles and phytoplankton. This gives us an idea of the types of phytoplankton that dominate the community.
BB3 : measures water turbidity , the concentrations of phytoplankton, and the average size of particles.
WSCD : measures the amount of dissolved, colored organic matter.
LISST Horizon : measures the distribution and size of particles.
IFCB : Imaging FlowCytoBot : analyzes the communities of plankton by continuous imaging.

Conserving the samples

Conservation

Liquid nitrogen -190° C | Freezer -20°C | Refrigerator 4°C | Ambiant temperature

Preparation

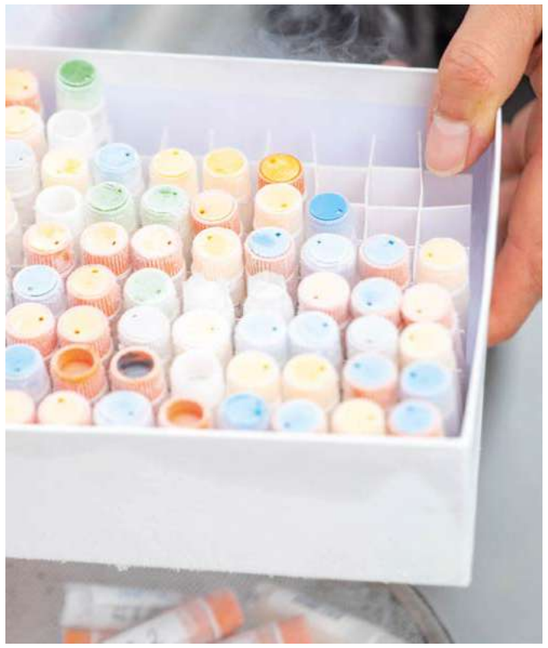
Natural sea water | Filtered sea water | Sea water with a poison | Filters | Sea water and filters in formaldehyde

Sending samples

Collected samples are sent every 3 months via World Courrier to the Génoscope, which then divides them up and shares them with all our partner laboratories for analysis.

23 partner labs in 10 different countries:
France, Spain, Argentina, South Africa, Germany, Netherlands, US, Italy, Brazil, Israel

400 scientists participate.



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Sharing Ocean Culture

Beyond the state-of-the-art research accomplished on board, Tara is also a marvelous means for raising awareness, bringing science and the Ocean closer to people everywhere. By inviting the general public and school children to come aboard during the Microbiome Mission, the Tara Ocean Foundation brought them into the heart of the Ocean during this scientific and human adventure. Everyone recognizes that the forest is indispensable for life on Earth, but the same should be true for the Ocean. From the work of scientists and artists accomplished during the schooner's missions, new tools for raising awareness are developed. Meetings are proposed to offer the public a chance to explore the Ocean from a new angle, and understand why the Ocean is the key to life on Earth.

17
stopovers for raising awareness

nearly
3 000
visitors (general public)

13
conferences with more than
800
participants

8
film projections with more than
500
spectators

nearly
6 000
nearly

more than
100
associations encountered

2 000
classes,
50 000
students followed the mission from France

©Maéva Bardy - Tara Ocean Foundation

Artists aboard the Microbiome mission

To explore and share - Each of the schooner's missions is intended to be a meeting and exchange between artists, scientists and sailors. The Tara Ocean Foundation not only transmits scientific knowledge through its expeditions; it also invites artists aboard for residencies.

Over the past 15 years, mission after mission, the Tara Ocean Foundation has continued to push back the frontiers of our knowledge about the largest and most important ecosystem on our planet - the Ocean. But the Tara Ocean Foundation not only transmits scientific knowledge through its expeditions; it is also a special place for artists. Science has always been a source of inspiration for artists. On the schooner, they observe and transcribe according to their sensitivity and imagination, the richness of the Ocean, the research and daily life on board. *Tara* left her home port on December 12, 2020 and returned to Lorient on October 15. Ten artists relayed one another during the *Microbiome* mission: 6 were winners of the «call for residency » and 4 others came aboard from the countries we traversed.

Leslie Moquin

Visual artist

August 16, 2021 to September 8, 2021

from Fort-de-France to Macapa

Aboard Tara, I went in search of the Green Ray: a physical phenomenon sometimes considered chimerical or even mystical. It manifests as a green flash radiating across the horizon during the first seconds of sunrise, or in the last moments of sunset. This fierce light did not show itself during my time aboard, or at least did not let itself be seen. But more than its capture, it was above all the pursuit which was at stake, and whose process I document.

Manon Lanjouère

Visual artist

October 12, 2021 to November 9, 2021

from Salvador de Bahia to Rio de Janeira

My project will attempt to lift the shroud over the people of the water - shadow people even less well known than the surface of the moon or Mars. Like the water we splash in our face, « the particles » wish to awaken this energy of seeing, transforming the gaze into a clear and easy action leading to real awareness. With the creative image, I propose to give a new form to the destroyed world of tomorrow by reinventing its structure: plastic materials become the new form representative of microbiomes.

Meet the artists

Photo 1 : ©Julie Nedelec-Andrade - Tara Ocean Foundation and photo 2 : ©Maéva Bardy - Tara Ocean Foundation

Antoine Bertin

Sound artist

November 28 to December 30, 2021

from Buenos Aires to Ushuaia

Aboard Tara, Antoine uses the data collected during the Microbiome mission as raw material for the composition of sound meditations on marine micro-organisms. This process of translating digital information into sound is called « sonification». It allows him to reveal to our ears the variations, rhythms and conversations of phytoplankton. By crossing scientific research, creative coding and musical composition, Antoine's goal is to create a series of works exploring the intelligence of the phytoplankton bloom.

Irene Kopelman

Visual artist

July 11 to August 16, 2022

from Pointe Noire to Banjul

Irene Kopelman is originally from Argentina; she settled in the Netherlands in 2002 to participate in a residency at the Rijksakademie van Beeldende Kunsten, in Amsterdam. Her interdisciplinary practice involves long-term collaboration with several research institutions. s« At Tara, I work with images generated by an instrument called the FlowCam which transforms seawater samples into two-dimensional images through a computer - thousands of images of a condensed sample collected at sea. The immensity of the Ocean in a tiny sample in which we can find thousands of samples had captured my attention. »

Giulia Grossman

Videographer

August 16 to September 4, 2022

from Banjul to Dakar

Giulia Grossman is a filmmaker. By combining an ethnographic approach with that of cinema, her films have a welcoming manner, a porosity to the context that make them eminently experimental. Implicitly, each of her films questions our way of inhabiting the Earth by putting man in relationship with the space surrounding him. « Zero to infinity gives us access to the imperceptible part of the ocean, its matter and composition, not visible to the human eye. The viewer is bathed in an indefinite universe that confuses our relationship to the visible and the invisible in these vertiginous oceanic landscapes. Filmed on the Atlantic Ocean and in the laboratories that study water, we will go from the immensity of the horizon to the abstraction of microscopic views.»

Lara Tabet

Visual artist

September 12 to October 4, 2022

from Dakar to Lisbon

Lara Tabet is a medical biologist and visual artist. Her work - at the intersection between photography, biology and environment - is anchored in research and experimentation. She is particularly interested in the interaction between photographic matter and the biological element, while questioning the porous borders between digital grammar and its counterpoint in emulsion photography. She uses old photographic techniques as well as new technologies and synthetic biology to explore this impetus to classify the living, and the tension between the bio-political and the bio-poetic. «I would like to use the photographic technique of printing with salt to create an atlas of marine life forms encountered on our way."

Photo 1 : ©Marin LE ROUX-polaRYSE • Tara Ocean Foundation, photo 2 : ©Guillaume Tauran • Tara Ocean Foundation, photo 3 and 4 : ©Maxime Horlaville • Tara Ocean Foundation

Photo 1 : ©Maéva Bardy • Tara Ocean Foundation, photo 2 : ©Alice Roy • Tara Ocean Foundation, photo 3 : © Arthur Larie • Tara Ocean Foundation
Photo 4 : ©Marin LE ROUX-polaRYSE • Tara Ocean Foundation, photo 5 : ©Guillaume Tauran • Tara Ocean Foundation, photo 6 : ©Maxime Horlaville • Tara Ocean Foundation

Gyotaku is an ancestral Japanese technique used by fishermen and scientists in the 19th century. It consists of immortalizing a fish on a sheet of rice paper using India ink or water-based paint. I discovered and adopted this technique during various visits to Japan with Tara. Gyotaku allows me in an artistic way to highlight this marvelous world of the Ocean, often unknown to the general public and essential for the future of our marine ecosystems.

François Aurat · sailor and artist


© Maéva Bardy · Tara Ocean Foundation

The Tara Ocean Foundation wishes to thank
everyone who made the Microbiome Mission come to be : the team on land, at sea, and the scientists who collaborated hand in hand for nearly 2 years to accomplish this expedition.

Team at sea

Samuel Audrain, Martin Hertau, Carole Pire, Léo Boulon, Sophie Bin, Nicolas Bin, Yves Tournon, Jonathan Lancelot, Paul Marre, Rémi Poizat, Loïc Caudan, David Monmarché, François Aurat, Louis Wilmotte, Alain Prieur, Mathieu Oriot, Laurent Rogniaux, Baptiste Regnier, Jimmy Le Floch.

Team on land

Etienne Bourgois, Romain Troublé, Anne Ghuysen, Marie-Sophie Bienfait, Carole Balducci-Helfer, Camille Lextray, Déborah Roussel, Marine Prost, Myriam Thomas, Marilou Bourdreux, Mila Nicola, Véronique Vezin, Laure-Emmanuelle Thiébault, Brigitte Sabard, Pascaline Bourgain, Maëlla Le Picard, Marine Cornuault, Clémentine Moulin, Aliénor Bourdais, Juliette Schramm, Thomas Linkowski, Thierry Mansir, Jean Collet, Romy Hentinger, André Abreu De Almeida, Henri Bourgeois Costa, Martin Alessandrini, Sylvie Duboué.

Scientific team

David Le Guen, Anna Oddone, José-Miguel Moll Kraft, Josep-María Erta Montejo, Douglas Couet, Miléna Cerda, Céline Dimier, Eric Pelletier, Rodrigo Torres, Emilio Alarcón, Camila Fernandez, Léa Olivier, Natalia Torres-Rodriguez, Stéphane Pesant, Nils Haëntjens, María Paula Huber, Andrea Santarosa Freire, Helena Cruz de Carvalho, Andréa Green Koettker, Alessandra Gomes, Xiomara Franchesca Garcia Diaz, Rubens Mendes Lopes, Pedro Junger, Alison Palmer Chase, Érica Caroline Becker, Samuel Chaffron, Constanze Kuhlisch, Flora Vincent, Morgane Ratin-Coz, Michel Flores, Emmanuel Boss, Lee Karp Boss, Gleice de Souza Santos, Alessandro Tagliabue, Nastassia Patin, Guillaume Bourdin, Chris Bowler, Rémi Laxenaire, Cora Hörstmann, Clara Trellu, Giancarlo Bachi, Ndamononghenda Mateus, Emma Rocke, Yi-Ting Ho, Thomas Leeuw, Nicole Dames, Thulani Makhalanyane, Mathilde Bourreau, Mancha Mabaso, Charlotte Begouen Demeaux, Suzana Nicolau, Damaria Ardène Boussiengué, Louis Caray, Roland Ngomo, Antonella Ruggiero, Jean-François Ghiglione, Karine Lebaron, David Leistenschneider, Eloïse Trabut, Noé Poffa, Ange Bouramanding Diedhiou, Leila Meistertzheim, Edouard Lavergne, Timothée Brochier, Muguette Allegre, Hugo Sarmento, Alejandro Maass, Stéphane Pesant, Daniele Iudicone, Colomban de Vargas, Gilles Reverdin, Lionel Guidi, Fabien Lombard, Marc Picheral, Stéphanie Kandels, Patrick Wincker, Chris Bowler.

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