RACE FOR WATER ODYSSEY

Assessment of the plastic pollution in the islands of the 5 gyres

General context and description of the scientific approach

Lausanne, March 2015

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Marine litter from fishing industry activities in a remote beach of Portugal (© F. Thevenon)

Setting the scene: The importance of plastics in the ocean

Despite the adverse effects of plastic pollution on marine organisms and ecosystems, the sources and the impacts of marine litter are still relatively unknown (Thevenon et al., 2014). It is generally considered that the majority of marine litter consists of plastic debris which originates from land-based sources. A part of this marine litter is nonetheless transported by ocean currents to open (or pelagic) oceans where prevailing currents can be favourable to the creation of relatively stable waters enriched in marine debris. This large-scale accumulation of plastic debris in pelagic oceans is often called “garbage patch”, “trash vortex,” or “gyre”. There are five oceans in the world, each with a gyre due to the global atmospheric circulation, and each with an anomalous high concentration of floating plastics (Cozar et al., 2014). However, to date, it is impossible to precisely map these plastic polluted areas and there is an overall absence of precise data about the sources, the transport and sink of plastic particles in these pelagic regions.

The drifting plastic debris have several adverse effects on marine organisms and ecosystems. The most visible and preoccupant impact of marine plastic pollution is ingestion, suffocation and entanglement of hundreds of marine species. Floating plastics also contribute to the transport of invasive marine species which threaten marine biodiversity. Floating plastic particles potentially accumulate toxic pollutants on their surfaces during their long- residence time in polluted water and can therefore represent a source of environmental pollution; but also serve as a vector for hazardous pollutants which accumulate in the food webs.

Microplastics are defined as fragments of a size smaller than 5 mm or 1 mm, depending on the different guidelines used for sampling and analyzing marine plastics (GESAMP 2010). The remote islands of the gyres are not only victims of the worldwide plastic pollution but also represent a sink and a source of microplastics. In fact, the ocean currents are pushing some large plastic items on their shorelines and in particular on the beaches where plastic debris accumulates with time. Additionally, the plastics washed onshore on beaches degrade into microplastics which can be thereafter spread offshore in coastal waters (Isobe et al., 2014).

A better knowledge of the gyre phenomenon requires important investments in both scientific research and fieldwork. To date, the existing data do not allow an accurate and comprehensive understanding of the impacts of marine plastics on marine organisms, food webs and biodiversity, as well as on human livelihoods and the global economy. This situation thus hinders an efficient implementation of the policies that are urgently needed for an effective reduction of the worldwide marine plastic pollution.

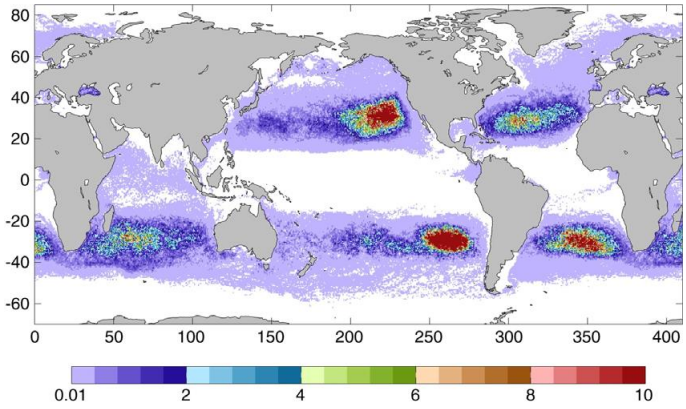
The characterization of the plastic quantities, polymer types and sources (terrestrial versus marine) from the islands located in the gyres can provide a valuable way to estimate the quantities and the types of plastics present in the remote parts of the oceans. In order to better understand the stocks, fluxes, sources and transport pathways of the plastic debris in the open oceans, the Race For Water Foundation will dedicate 310 days to investigate 11 islands located in the 5 ocean gyres.

1. The problem of plastic pollution in the oceans

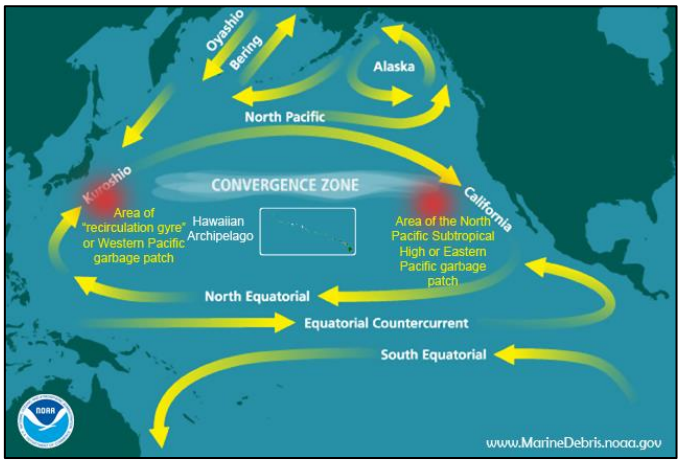
Marine debris is defined as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed or abandoned into the marine environment (Galgani et al., 2010). Marine debris primarily comes from land- based sources including urban and storm runoff, sewer overflows, beach visitors, inadequate waste disposal and management, industrial activities, construction and illegal dumping. The rest (i.e., ocean- based sources) principally derives from the fishing industry, nautical activities and aquaculture. However, the quantity and the source of marine debris highly vary according to local human activities: importance of fishing and tourism, the presence of large urban centers and the discharge of domestic and industrial wastewater, riverine input and industrial or agricultural activities.

Floating debris in the River Citarum (Indonesia). © Dadang Tri / Reuters

Plastics debris represents the main proportion of total marine debris and can even reach as much as 90 to 95% of the total amount of marine litter. A significant part of the manufactured plastics is buoyant in seawater because of their low densities. Moreover, marine plastics degrade very slowly in the environment and especially in water. As a consequence, floating marine plastics can be transported by ocean surface currents over long distances. In fact, the abundance of plastics in the marine environment primarily varies spatially as a function of the distance to coastal populated areas and popular tourist destinations, as well as with the occurrence of heavy rain and flood events; but also with the direction of the surface currents which control the transport and the accumulation of plastic debris, including in the 5 oceans gyres which are located in the North and South Atlantic, in the North and South Pacific and in the Southern Indian Ocean.



Model simulation of the possible distribution of marine litter in the ocean after ten years showing the plastic debris converging in the 5 major ocean gyres. (Source : IPRC 2008)



This map is an oversimplification of ocean currents, features, and areas of marine debris accumulation (including "garbage patches") in the Pacific Ocean. There are numerous factors that affect the location, size, and strength of all of these features throughout the year, including seasonality and El Nino/La Nina. (Source: Marine Debris Program)

Municipal waste stream represents a significant but relatively unknown source of microplastics, in the form of plastic fibers from washing synthetic clothes and microplastic scrub beads (e.g. polyethylene and polypropylene) used in personal care products and cosmetics. These particles that are generally smaller than 1 millimeter are designed to be washed down the drain even though they are not captured by wastewater treatment plants. The other source of micro-plastics in aquatic environment originates from the degradation of large debris by chemical (ultraviolet radiation, oxygenation), physical (wind, wave) or organic (bacteria) degradation processes in the environment.

Despite the growing general awareness about the abnormal presence of plastics in remote pelagic areas, the public should keep in mind that plastic pollution in the gyres does not form compact accumulation zones of marine litter (e.g., a mythical plastic continent) but rather diffuse areas of plastic pollution, i.e., zones containing higher concentrations of plastics than the waters of the open ocean in general. Their mapping is however complex because there is yet no technical way to detect these plastics which can float a few centimeters below the surface waters. Moreover, the plastic pieces are vertically distributed within the upper water column due to wind-driven mixing and are often invisibles to the naked eye and unidentifiable by aerial/satellite photos.

1.1 The impacts of plastics on marine ecosystems

Marine litter has adverse effects on marine wildlife and directly affects marine ecosystems. A synthesis report by Greenpeace about the impact of plastic debris on marine wildlife indicates that at least 267 different species are known to have suffered from entanglement or ingestion of marine debris, including 86% of all sea turtle species and 44% of all sea bird species, while 70 to 100% of the albatrosses are known to ingest plastics (Allsopp et al. 2006). Marine plastics can cause death by drowning, suffocation, or strangulation. Even if not immediately lethal, entanglement can produce lacerations and infections from the abrasive or cutting action of attached litter, or impair the ability of animals to swim and therefore to find food or escape from predators.

Ingestion of plastic debris by marine fauna (© from left to right A. Fallabrino, C. Jordan, Algalita)

Micro-plastics suspended in surface water can be ingested by aquatic organisms, including animal plankton; while toxic chemicals (e.g., Persistent Organic Pollutants, POPs) are potentially present on their surface (adsorbed). Furthermore, the plastic material under the effect of its disintegration, can release intrinsic toxic compounds. These compounds which were added during their manufacture to improve their qualities (flame retardant, PCBs, bisphenol A, phthalates) can thereby contaminate the food chain and eventually be ingested by humans. Finally, floating plastics create new habitats that further enable the transport of invasive (alien) species over long distances. These invasive species represent a major threat for endemic species and marine biodiversity.

Floating plastic items provide a hard substrate for marine organisms that last much longer than most natural floating substrates and allow them to be transported over long distances (© F. Thevenon)

1.2 Filling knowledge gaps through standardized research methods

Since a few years, many initiatives have been undertaken, not only to improve our knowledge about marine litter, but also to foster a sense of individual responsibility and to encourage public and private initiatives for reducing plastic pollution in the world's oceans; such as the volunteer beach cleanups for removing beach debris (Ocean Conservacy 2014). Despite the growing interest in the phenomenon of plastic marine pollution, the knowledge about marine plastic is still incomplete and hinders the ability to solve the problem efficiently and effectively.

The widespread distribution of plastic debris in some remote parts of the oceans that are difficult to access, is a major obstacle; but it is also widely accepted that another key factor that limits the better understanding of marine plastic issues, results from the difficulty of comparing quantitatively the existing studies using different analytical protocols.

Twenty years after the conference of the United Nations (UN) in 1992 in Rio de Janeiro, the marine litter was one of the main topics of the Rio + 20 Conference held in June 2012. The UN Member States adopted the final document Rio + 20, "The Future we Want", based on the results of the conference held in Honolulu in 2011, co-organized by the United Nations Environment Programme (UNEP) and by Atmospheric and Oceanic National Administration of the United States (NOAA). **The Honolulu strategy**, a global framework for the prevention and management of marine debris, encourages all stakeholders concerned to find innovative solutions and initiatives to address the marine litter problem, including by sharing best practices, technical information about capacity building, and legal, policy, community-based, economic and market-based means of preventing, reducing and managing marine litter (UNEP and NOAA 2011).

2. Race for Water Odyssey: Studying the islands in the gyres

The islands located in the gyres act as a natural barrier to the long-term transport of marine plastics, by trapping the drifting plastics on their shores. These remote islands thereby become indirect victims of the long-range transport of the plastics mainly released by human activities on the continents. As a matter of fact, their beaches provide valuable and representative sites for evaluating the types and the quantities of plastics that are present in the surrounding waters.

The Race for Water Foundation aims to achieve in less than one year, an inventory of the plastic pollution in some remote islands from the North and South Atlantic gyres, the North and South Pacific gyres, and the South Indian Ocean. The shorelines of these islands will be investigated using the same standardized scientific protocols. This unique expedition will therefore provide an evaluation of the quantities and types of floating plastics in some islands of the 5 different gyres, with reliable and comparable data sets; while the majority of the previous expeditions generally investigated on gyre per mission and mainly focused on the quantification of the microplastics present in the surface waters (using plankton nets for retrieving the plastic particles).

2.1 Scientific research during the Race for Water Odyssey

The studied islands have been selected according to their locations in the gyres. There are 11 islands, most of them located far away from civilization while some islands are even inhabited. The selected habited islands lack of significant industrial activities and mainly depend from tourism and local activities such as fishing. The route of the Odyssey has been divided into 5 legs through the 5 gyres.

Expedition 1 – North Atlantic Patch

- Azores: Portugal; 2,333 km^2; 245,746 habitants
- Bermuda: United Kingdom; 53 km^2; 64,237 habitants

Expedition 2 – South Pacific Patch

- Easter Island: Chile; 164 km^2; 5,761 habitants

Expedition 3 – North Pacific Patch

- Palmyra Atoll: USA; 12 km^2; no permanent population
- Midway Atoll: USA; 6 km^2; 60 habitants
- Wake Island Atoll: USA; 7 km^2; 150 habitants
- Mariana Islands: USA; 1020 km^2; 251,000 habitants
- Koror: Republic of Palau; 380 km^2; 11,200 habitants

Expedition 4 – South Indian Patch

- Chagos Archipelago: United Kingdom; 56 km^2; 3000 habitants
- Rodrigues: Republic of Mauritius; 108 km^2; 38,379 habitants

Expedition 5 – South Atlantic Patches

- Tristan da Cunha: United Kingdom; 207 km^2; 300 habitants

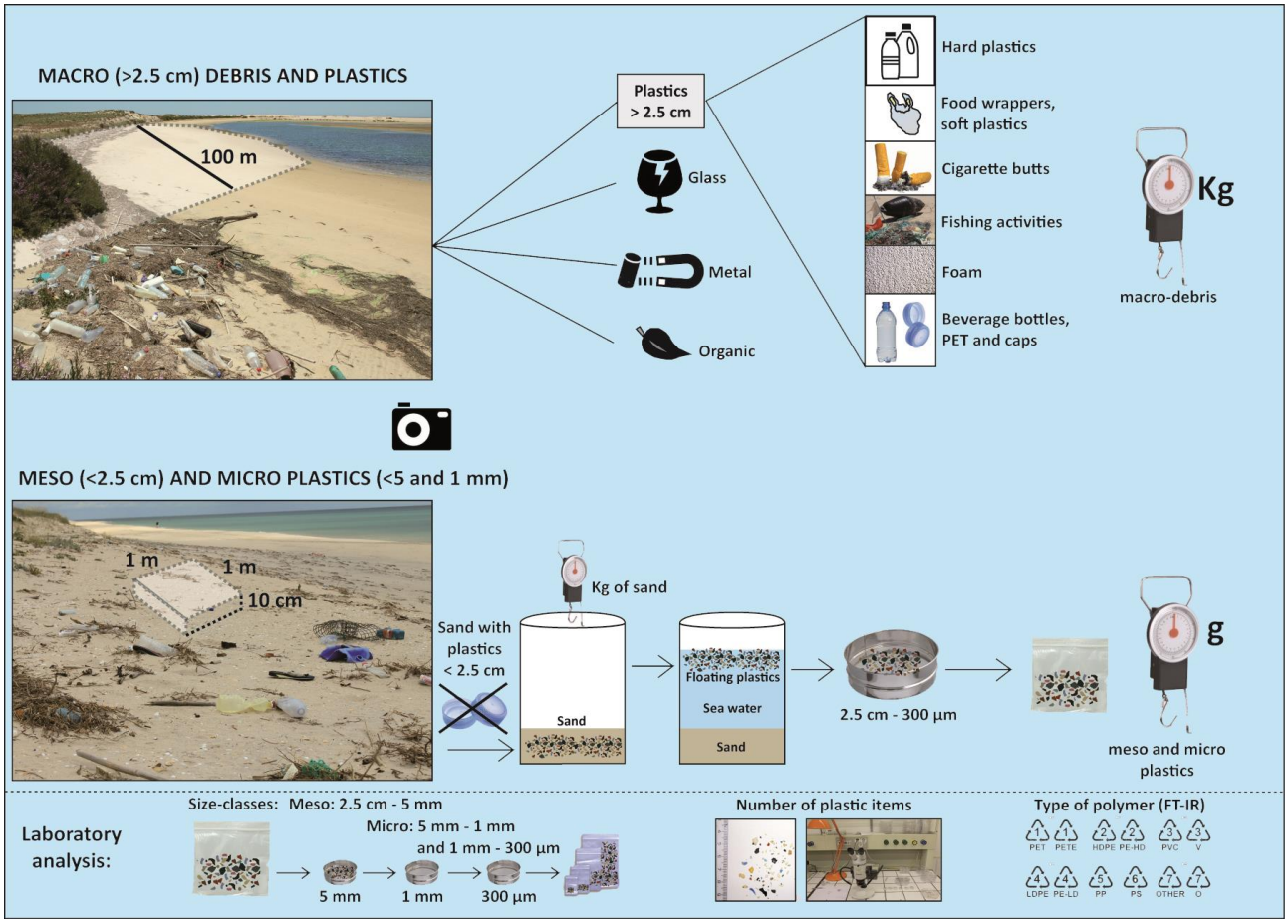
2.2 Description of the scientific protocol

In collaboration with the local partners of the Odyssey (scientists, NGOs and International Organizations), some measured shoreline sections (a minimum of 100 m in length parallel to the seawater) will be studied following the NOAA Marine Debris Shoreline Survey Guide (Opfer et al., 2012; Lippiatt et al., 2013); taking into account the date on which the last survey was conducted to estimate the rate of deposition (flux) of debris onto the shoreline (accumulation studies).

Concerning the areas that have never been cleaned before, the assessment of the total load of debris will be used to determine the density (number of items per unit area) of debris present; reflecting the long-term balance between natural debris inputs and removal (standing-stock studies).

After their manual collection on the studied shorelines, the "macro-debris" which are arbitrary defined as superior to 2.5 cm (~bottle cap size) will be categorized according to their material category (plastic, glass, metal, rubber, paper/processed lumber, cloth/fabric and other non-classifiable debris; Opfer et al., 2012) and origin (offshore due to fishing activities). Each category of waste will be then precisely weighed and the volume will be eventually estimated. When identifiable on the plastic item, the geographical origin of the litter will be noted.

For extracting the "meso-debris" (5mm - 2.5 cm) and the "micro-debris" (<5 mm) from the sandy beaches, researchers will delimit 1 m^2 where the top 10 cm of sand will be collected using a stainless steel shovel. The sand will be then placed into a container where seawater (density ~1 g cm^3) will be added. The plastic particles that will naturally float on the surface of the seawater will be retrieved using a 300 micrometer (µm) fine mesh. The extracted plastic particles will be send to the EPFL laboratory (Switzerland) to be sorted in different size classes (5mm, 300 µm), and further categorized using a binocular microscope based upon their color or origin (e.g., plastic pellets which are the industrial raw material that is used to manufacture plastic products). Some small plastic particles will be also analyzed by Fourier Transform Infrared Spectroscopy (FT-IR) in order to identify the polymeric material (e.g., polyethylene terephthalate, PET, foam).



The Odyssey expedition is also an opportunity to test new technological tools of exploration and to develop an effective method to locate marine debris using civil drone technology. Such methodological development is essential to identify marine debris on remote and unpopulated shorelines and to increase marine debris removal – ultimately resulting in a decrease of marine debris accumulated even if current levels of introduction from land-based and at-sea sources remain constant (UNEP and NOAA 2011). For the first time at such a large-scale, high resolution mapping (with an accuracy of up to 5 cm per pixel) using low-altitude flights (~ 100 m) will be carried out to provide digital reconstruction of the surveyed beaches.

The data gathered by the drone will be processed in the laboratories of Duke University (US). The analysis of the collected images will be compared with the litter data obtained by manual collection. This approach will allow to calibrate or at least to evaluate the precision of this new technique for detecting macro-debris. Such a new tool is crucial for improving the efficiency and effectiveness of marine debris removal efforts according to the Honolulu strategy (UNEP and NOAA 2011).

A drone (eBee from the Swiss company Sensefly) will be used for mapping at high resolution the studied shorelines.

The low-flying drone surveys combined to Real-time Kinematic-Global Positioning System (RTK-GPS) system will also provide a precise baseline of sea level measurements. This procedure will be applied on all the studied islands to create a baseline set of the current sea level measurements/beach profiles that could be used for future studies; for instance regarding the impacts of global-warming induced sea-level rise on coastal environments, the natural erosion and accretion processes driven by storm surge events, etc.

3. Main partners

The scientific research in the frame of the Odyssey will be conducted in collaboration with some universities and research centers that have a high-level of expertise in the analysis of plastic debris in the environment, and in the acquisition and treatment of drone data. The project is also supported by international organizations for the protection of nature whose goal is to provide to the economic actors, policy makers and the public at large, a comprehensive statement about the current state of knowledge of the (micro-) plastic pollution in the 5 gyres.

3.1 Swiss Federal Institute of Technology Lausanne (EPFL) – Switzerland

Located on the shores of Lake Geneva in Switzerland, EPFL is a federal academic institution specialized in the field of science and technology. EPFL has an international reputation thanks to the quality of its academic programs and research projects. International academic rankings consistently place the institution among the best schools in the world in the field of natural sciences, engineering and technology.

The Central Environmental Laboratory (CEL) which is run by Dr. Luiz Felippe De Alencastro covers the main traditional techniques applied in chemical and physical analytical chemistry, and conducts its own researches in environmental analytical chemistry. This ecotoxicology laboratory is specialist in the analysis of organic micro-pollutants, e.g. POPs, pesticides, PCBs, PAHs,

pharmaceuticals, etc., in environmental matrices. The CEL has extensive experience in the analysis of microplastics from the aquatic environment (planktonic waters, beaches, fishes and birds).

In the frame of the project Odyssey, microplastics will be sorted in different size classes and material categories, while Fourier-transform infrared spectroscope (FT-IR) analysis will permit the identification of the polymers from the microplastics collected on the beaches of the islands from the 5 gyres.

3.2 Duke University – United States

Duke University is a North American research university located in North Carolina. It is one of the most prestigious universities in the world, especially in the fields of marine research. The research lab at the Duke University Marine Laboratory will support one Master's student enrolled in the Nicholas School of the Environment's Coastal Environmental Management (CEM) Program to analyze imagery collected during the Odyssey expedition and to develop protocols for detecting and quantifying macro-plastics and other anthropogenic debris. The students involved in the project will be able to make extensive use of the new visualization facility at the Duke Marine Lab – the Coastal and Ocean Visualization Environment (COVE–see http://superpod.ml.duke.edu/cove/) for their project.

The group of Dr. David W. Johnston, Assistant Professor of the Practice of Marine Conservation & Ecology, will help for the pre-programmation of the drone and will be responsible for analyzing the collected data. The team has significant expertise in conducting drone operations since they are using unmanned aerial systems (UAS) for studying marine mammals in the Arctic. In addition to this field expertise, Duke University will also be a key partner for organizing some events in the USA (New York and Hawaii).

3.3 Oregon State University (OSU) – United States

Oregon State University (OSU) is a North American research center well-known in the areas of oceanographic and atmospheric sciences. The institution operates the Hatfield Oceanographic Centre, located on the shores of the Pacific Ocean. This laboratory is distinguished by its research programs on marine fauna and flora.

The team of Dr. Ari S. Friedlaender, Associate Professor at the Marine Mammal Institute, will take part in the Odyssey mission by working closely with Duke University in the exploitation of data acquired by the unmanned aerial vehicles (UAV).

Using the drone technology developed by SenseFly, the eBee will be used to conduct fine-scale aerial mapping surveys that will allow us to produce orthomosaic maps, 3D elevation models, and geo-referenced imagery with relative accuracy down to 3 cm.

3.4 The United Nations Environment Programme (UNEP)

The United Nations Environment Programme (UNEP) is an agency of the United Nations (UN), created in 1972 that aims at coordinating United Nations activities in the field of environment and that assists countries in the implementation of environmental policies. Since the concept of sustainable development was forged (Brundtland, 1987), UNEP has sought to integrate environmental issues into wider sustainable development policies.

As part of the collaboration between UNEP and the Race for Water Odyssey, a conference will be held at the UN headquarters when the Expedition stops in New York.

3.5 International Union for Conservation of Nature (IUCN)

The International Union for Conservation of Nature (IUCN) is the world's oldest and largest global environmental organisation. IUCN's mission is to influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is equitable and ecologically sustainable." It has a membership of over 1200 governmental and non-governmental organizations. IUCN employs approximately 1000 full-time staff in more than 60 countries. Its headquarters are in Gland, Switzerland. It has been involved in establishing the World Wide Fund for Nature. Some 11,000 scientists and experts participate in the work of IUCN commissions on a voluntary basis. IUCN is involved in data-analysis, research, field projects, advocacy, lobbying and education. IUCN has an Official Observer Status at the United Nations General Assembly, and plays a role in the implementation of several international conventions on nature conservation and biodiversity. It is best known to the wider public for compiling and publishing the IUCN Red List of Threatened Species, which assesses the conservation status of species worldwide.

IUCN is an active partner of the Odyssey whose representatives will be present on some islands of the gyres. IUCN will also support the Race For Water Foundation for organizing some scientific/public events at some stopovers of the Odyssey.

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