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Plastic and Us: looking at the marine litter problem from inside the rubbish. An unusual temporary exhibition at the Natural History Museum of the University of Pisa

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Abstract

In this paper, we will describe a temporary exhibition held at the *Museo di Storia Naturale dell'Università di Pisa* (Natural History Museum of the University of Pisa, hereafter MSN), Italy, in year 2020-2021, and the educational and awareness raising results that the proposed approach has produced. The aim of this exhibition was to guide the visitor along a path of awareness on the very topical issue of "plastic in our environment". It focused not only on the environmental impact produced by the dispersal of anthropogenic plastic waste, especially in the sea, but also on the awareness of what actions need to be taken, both on a governmental and personal level, by each of us, to limit it in the future. The exhibition started from the data and images proposed by the media, which shocked us with the seriousness of the plastic emergency and triggered worldwide attention. Then the emphasis of the exhibition shifted to scientific data, rigorously presented by researchers who study the issue directly in the field, in the Mediterranean Sea and along its coasts. Finally, the last exhibits addressed the issue of plastic disposal, inviting visitors to check their real knowledge about the concepts of degradable, compostable, or recyclable plastic, and to reflect on what could be the most effective means to limit plastic problems in the future. The plastic problem is exquisitely anthropogenic, and the exhibit was designed to make visitors feel involved. The mismanagement of the lifecycle of this material (from manufacturing processes to products' end life) can be addressed on a global scale by drastically reducing the use and production of single-use plastic items, promoting proper waste management, and improving the effectiveness of recycling. The exhibition message was that laws are essential, as well as calling plastic producers to their responsibility, but something can also be done locally by us as individuals, through proper disposal and by producing less single-use plastic waste. Visitors' attitudes and knowledge on this topic were investigated through online questionnaires prepared by experts in the field, and the data collected are presented and discussed in this paper.

Keywords: Ocean literacy; marine litter; environmental plastic impact; museum exhibition; virtual visit; educational games.

Introduction

Following the initiative of the Intergovernmental Oceanographic Commission of UNESCO, in 2017 the United Nations established the *Ocean Decade*, a ten-year plan (2021-2030) dedicated to marine sciences, ocean protection and socio-economic development in harmony with environmental balances (https://www.oceandecade.org). The *Ocean Decade* will debut with the aims of involving the scientific community, politicians, businesses, and civil society in identifying effective and urgent responses that can translate into a real change. The actions promoted by the *Ocean Decade* should result in a deeper understanding of current and future ocean conditions, anticipating their change and their impact on human well-being and the economy. This will involve the production of data and information about the ocean, to which all nations will have the right of open access. The resources dedicated to marine science will also increase the presence of these issues within educational programs, both those aimed at citizens' awareness and scholastic ones. Indeed, it is important that global citizens, of today and tomorrow, understand the social impact of oceanic research and pressing ocean issues; hence the importance

of the role that Ocean Literacy will play in the next decade. Ocean Literacy is more than just informing the public and maritime stakeholders about the importance of the ocean: "Ocean Literacy aims to facilitate the creation of an ocean-literate society able to make informed and responsible decisions about ocean resources and ocean sustainability" (Santoro *et al*., 2018).

Among the global environmental problems that are affecting our seas (ocean acidification, climatic changes, biodiversity loss etc.), plastic pollution represents one of the most urgent to be faced, being related to many aspects of our daily life, and affecting our health (Wright & Kelly, 2017). It is mainly caused by the excessive production - especially single-use items and packaging, which have further increased in recent years due to the coronavirus pandemic (Silva *et al*., 2021; De-la-Torre *et al*., 2021; Ben Haddad *et al*., 2021) - and consumption of this material, but also by its incorrect disposal. As Mediterranean Sea concerns, Egypt, Italy, and Turkey are the three countries from which more than 50% plastic litter leakage gets into the sea (Boucher & Billard, 2020). In recent years, in many EU countries serious legislative actions are being taken to limit this problem and the results will hopefully be seen in the years to come (EU SUP Directive, 2019; Lau *et al*., 2020; The Pew Charitable Trusts & SYSTEMIQ, 2020; Eunomia, 2021). As for Italy, although the Italian Parliament has banned microbead scrub particles in cosmetics as of 2020 and cotton buds made of non-compostable plastic as of 1 January 2019, the adopted regulations still seem to lack a structural vision, strongly skewed towards the replacement of single-use items in traditional plastic with similar single-use items in compostable bioplastic (see the Greenpeace Italia report, concerning the problematic implementation process of the EU SUP directive in Italian law; Greenpeace, 2021). As a matter of fact, like other nine EU countries, Italy has not yet transposed the EU SUP directive banning ten single-use plastic products into its national law (EU SUP Directive, 2019).

Several scientific studies find that people's good practices, although important, are not enough to substantially reduce the plastic pollution, and that campaign to reduce marine littering "do not significantly affect the amount of litter leaked to the environment" (Boucher & Billard, 2020). Surely, the responsibility of changing the current complex system from production to disposal of plastic items cannot be left solely on the shoulders of citizens and their "eco-sustainable" behaviour. All the involved actors, starting with the manufacturing industry (Delemare Tangpuori *et al.*, 2020), should play their part, also driven by the introduction of *ad hoc* legislations (Crippa *et al.*, 2019). On the other hand, it is also recognized that the involvement of educated and aware citizens is important for making laws more effective. Just as an example, it seems that a mutual reinforcement exists between norms and personal norms and behaviour about the household recycling in USA (Huber *et al.*, 2018). Alpizar *et al*. (2020) review evidence that combining charges with public engagement campaigns has usually more successful than introducing charges by themselves. Other studies suggest that environmental education plays an important role in reducing plastic consumption (Hartley *et al*., 2015, 2018a; Phan Hoang & Kato, 2016) and in reducing plastic litter on the beach (Cingolani *et al*., 2016; Rayon-Viña *et al.*, 2018). The educational institutions may play an important role in this process (Hartley *et al.*, 2018b), promoting the knowledge of these problems in citizens (e.g., of which are the most impacting plastic categories, on which are the problems connected with their production, commercialization and disposal) and explaining effective strategies for dealing with them both at a global level (e.g., regulation and laws at local and European level) and locally. As stated in Vegter *et al*. (2014): "*Delivery of an education and awareness strategy to minimize current and future impacts of plastic pollution on marine wildlife and habitats requires developing and distributing messages aimed at altering human behaviors associated with the manufacture, purchase, use, and disposal of plastic products. The message needs to be built on a communication and interpretation science and on accurate scientific information and to be delivered to the public and decision makers through traditional and social media, conferences, popular press, websites, and advertising*." Regarding the communication strategies, there are studies focused on ways to motivate consumers for more sustainable plastic consumption patterns (e.g., Hutner *et al*., 2018; Zwicker *et al*., 2020; Septianto & Lee, 2020).

Based on these considerations, the idea of the temporary exhibition "Plastic and Us" was born, held in the Natural History Museum (*Museo di Storia Naturale*, hereafter MSN) of the University of Pisa, which is located inside the Certosa of Pisa in Calci, Tuscany, Italy (Battaglini *et al*., 2020; Farina *et al*., 2021). In designing the layout and the themes exhibited, we focused on two main points:

- to make the Museum visitors aware of the problems of the accumulation of marine litter in areas "close" to them, specifically in the Marine Protected Areas of the Province of Pisa. This is also with the aim of raising awareness of the problem among the main users of these sea areas, and to make them acknowledged of what can be done to improve the situation, starting from the local level.
- to design a "low cost", modular and adaptable exhibition, which does not require large structures and large expenses for setting up, and which is therefore reproducible in the future by other museums, public institutions, schools etc. that want to propose a similar educational path, maybe adapting it to their own local/national situation.

Finally, the exhibition also represented the context in which we could investigate the knowledge and engagement of the public about ocean literacy with the aim of disseminating and educating on a specific and particularly topical issue, namely the pollution of the marine environment by plastic waste.

The restrictions due to the COVID19 pandemic greatly affected the interactive aspects and limited the possibility to engage visitors on site. Virtual tours (or, better:

live guided tours) were planned and organised; online games substituted the direct interactions, and the structural deficiencies were made up with a resilient attitude.

In this work, we will present the basic ideas on which the exhibition was set up and the results we obtained in a survey performed with a sample of students about their knowledge of the topic and their engagement in the exhibition.

Material and Methods

The temporary exhibition "Plastic and Us" was designed and realized by the staff of the Museum in collaboration with experts from two research bodies ISMAR – CNR and INGV.

The exhibition was initially conceived to be a highly interactive experience, especially designed for classes of students, in which the visitor would be able to touch and manipulate the objects, carry out didactic workshops related to the exhibition and participate in structured group activities. All of this was unfortunately made infeasible by the COVID19 emergency which, delaying the opening of the exhibition to the public until July 2020 and causing the closure of the Museum at the beginning of November 2020, reduced the exhibition accessibility to about three months. Furthermore, even in the periods of opening to the public, the COVID19 restrictions prevented the interaction with the exhibits due to the impossibility of touching them, as well as the realization of the didactic workshops/laboratories, initially planned as an integral part of the itinerary. In order not to completely lose the interactive experience, several changes were adopted as described in the following.

The key concepts behind the scenes of an exhibition

In recent years there has been a proliferation of exhibitions, documentaries, hands-on experiences dedicated to the problem of plastics in the environment and especially at sea. Most of them have combined the informative/scientific aspect (also providing quantitative data on its production, consumption, distribution, and interaction with the environment) with an artistic aspect, often preferring the latter through the realization and presentation of artefacts of great media impact. On the contrary, our intention was to present a route that could be done in a relatively simple way, and with easily available material to ensure replicability.

In looking for the communication key to provide scientifically correct information along with emotional messages, to inform and engage people at the same time, the whole exhibition was built upon some simple questions. How much single-use plastic objects would we have in our homes in a month if it were not collected once a week? How much space would it occupy? What are the types of plastics found most frequently dispersed in the environment? Are they among the ones that we use daily? Thinking at a very personal level, could we limit the production of plastic waste by paying more attention to what we buy and use? And, finally, is plastic the best possible material for everything? Many of its characteristics (lightweight, waterproof, durable, etc.) make it adaptable to a wide variety of uses; moreover, its production is inexpensive (Thompson *et al*., 2009; Geyer *et al*., 2017), all of which has contributed to its enormous diffusion: can we envision a future in which its use is greatly diminished?

Furthermore, the exhibits were built to show plastics that everyone uses and throws away on a daily/monthly basis. To this end, starting from November 2019, the staff of the Museum collected, washed, and preserved their own plastics and then used it to create some of the installations of the exhibition. At the same time, the aesthetic impact could not be neglected, as it was an important factor able to capture the attention of visitors and engage them into the topic. In accordance with the exhibition concept, the authors decided to use their waste to "pollute" the Gallery of Cetaceans[1], the most representative and engaging room of the Museum. At the entrance of the Gallery, plastics of various shapes and colours were hung from the ceiling, floating above the heads of visitors, and outlining the surface of an invisible sea in which dolphins and whales swim (Fig. 1a). The expected result was to elicit a shock effect in visitors[2]. Other exhibits have been built with the everyday plastics collected and quantified by the museum staff; some of them accurately represented common habits regarding the purchase and consumption of food, beverages, consumer goods, with their packaging: all things that often were not considered in relation to what was dispersed in the environment. The exhibition panels were designed so that visitors could easily access the scientific data regarding the problem of the dispersion and fragmentation of plastic waste (including the Covid-19 disposable masks and gloves; Klemes *et al*., 2020; Gorrasi *et al*., 2021) in the marine environment and, especially, in the Mediterranean Sea (Fossi *et al*., 2014; Cózar *et al*., 2015; Suaria & Aliani, 2014; Suaria *et al*., 2016; Giovacchini *et al*., 2018; Vlachogianni *et al*., 2018). The texts emphasised the role played by scientific research in this area, the results of which highlighted the harmful effects of plastics on the marine environment, in the Pelagos Sanctuary, a Specially Protected Area of Med-

1 The Gallery of Cetaceans was once a covered loggia used by monks for walking in the days of bad weather and for drying the agricultural products. This over-100-meter-long gallery houses about 30 cetacean specimens of the over 50 skeletons (seven of which between 12 and 23 meters in length) of the Pisa osteological collection of Cetaceans and is considered one of the most important in Europe for the variety and rarity of the species housed. Fossil specimens and life size models are also part of the exhibit since its complete renovation in 2018.

2 In such a display, the quantity, size, and density of "floating" objects was forcibly exaggerated and did not exactly reproduce what really happens in our ocean and seas, where the effect of the presence of mainly microplastics is better described with the words "plastic soup" rather than "plastic island" (Suaria *et al*., 2016). The explanatory panels that accompany this, as well as all the other exhibits at each station, provided the correct picture of the situation.

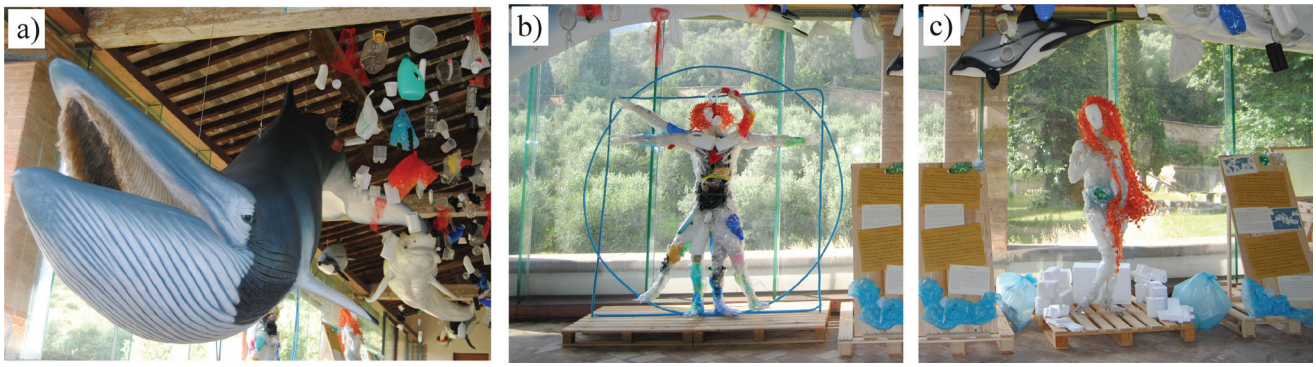

Fig. 1: **a)** Plastic Vortex. The plastic rubbish hanging from the ceiling of the Gallery of Cetaceans delineates the surface of a polluted sea in which whales and dolphins swim. Even if not completely realistic and forcibly exaggerated, such a setting is functional to elicit the desired "shock effect" in the visitor. **b)** and **c)** Plastic sculptures. Two icons of art as the Vitruvian Man by Leonardo da Vinci and the Birth of Venus by Sandro Botticelli, representing harmony and beauty, have become plastic statues, realized by artist Lorenzo Possenti using the plastic waste collected by the Museum staff, with the aim of making visitors reflect on the risk that pollution represents for our present and, above all, for our future.

iterranean Importance (SPAMI) (https://www.sanctuaire-pelagos.org/en/about-us/spami-what-does-it-mean) and, more generally, on the entire biosphere of our planet.

As educators, committed to conveying messages that can stimulate a better knowledge of the environment and the will to preserve it, we chose to point out not only the problems but also some possible solutions. Among them, as reported in the "Introduction", there are laws and norms to reduce the production of plastic objects, especially single-use packaging, incentives for the plastic recycling and reuse, economic pressures to companies for limiting the plastic packaging and other actions at global scale. At the same time and at personal and local level, we suggested some good practices that limit, even if only partially, the production and dispersion of plastic waste by promoting environmentally sustainable behaviours.

In essence, both the materials used, and the method adopted in the setting up of this exhibition aimed to improve visitors' knowledge and stimulate awareness of the problem, in addition to encouraging more environmentally friendly behaviour in the future generations.

Organization of virtual visits

The COVID19 emergency in 2020 and 2021 has tremendously affected the educational function of places such as museums, exhibition spaces and, in general, has caused significant problems for education and teaching. The exhibition, initially conceived to last one year and to host numerous classes of schools of different levels, had to be reorganized. Above all, it seemed essential that students, already greatly damaged by the contingent situation, could access the information and stimuli of our exhibition. Therefore, due to the impossibility of the direct visit, that was turned into a virtual one for interested school classes. This kind of visit had not been experimented before in the MSN, neither for temporary nor permanent collections. The digital equipment in the museum consisted in a tablet, secured to a tripod to avoid annoying movements, the tablet's camera and the wi-fi connection to interact with the public at home. The operator/guide was equipped with a microphone and headphones, and visitors heard her explanations, while watching through the tablet's camera. The live explanations were interspersed with short videos, previously prepared, on the different insights: the one on monitoring carried out (also, in some cases, with the help of drones and/or with citizen science approach) for research and classification of marine litter on the beaches of Tuscany; the one to more deeply understand the chemistry of polymeric materials, created in the form of a movie by using the material originally available in touch-screen format and prepared by CNR (National Research Council) researchers working in this specific field; and finally the one on the industrial recycling of plastics, prepared by the Tuscan company REVET[3], in which the chain of the process of recovery and reuse of plastic was explained and illustrated through funny and interesting examples.

Connected via tablet, the visitor could interact with the exhibits through the intermediation of the guide, who performed the suggested actions on them. In this way, it was possible to guarantee, particularly for children and teenagers, a certain degree of interactivity, which hopefully helped students to better appreciate the didactic path and the discussed topics. This type of visit entailed a considerable investment by the Museum, and therefore could not be made available to all potential visitors, but it was adopted only for organized school visits.

3 Founded in 1986, Revet is a leading company in the treatment of waste materials for the recycling industry. It operates mainly in Tuscany where it processes over 80% of the collected packaging. Revet transforms polyolefine fraction of collected waste into granules suitable to produce many different second-life plastic objects; moreover, it recycles the tetrapack.

On-line games realization and questionnaire administration

Some of the exhibit-games, designed to be interactive but temporarily available only in "look but don't touch" mode, were transformed into online game-quizzes. They were elaborated with Google tools (see Appendix), which allowed people to fill them out both remotely and on site, being freely available by means of a QR-code placed at the side of the corresponding exhibits.

For example, they were designed to be side-by-side with the two exhibits that will be described in Result paragraph, dealing with the problems of "how long it takes plastic to degrade in the marine environment" and "what are the effects it causes if it interacts with marine organisms", respectively. After the virtual participation in the game, students were invited to fill in the two short questionnaires (game-quiz) related to the topics covered. During this short rest from the virtual visit, they were able to prove what they have just learned and test their skills.

Besides their main purpose, *i.e.,* allowing visitors to interact virtually with the exhibits, the Google forms allowed us to collect a series of useful data for evaluating some aspects of this interaction.

In the example previously described, it allowed us to know how much knowledge students had acquired about the two specific topics thanks to the virtual visit. We administered the same games-quizzes both to a sample of students who took part in the virtual visit (69 students) and to a control group, that is a sample of students who had not visited (neither physically nor virtually) the exhibition (71 students), for a total of 140 interviews.

Moreover, in addition to these two online game-quizzes specifically related to the two cited exhibits, we decided to administer a third questionnaire to students participating in the virtual visit (end-of-course questionnaire), through which we investigated the level of knowledge of the students interviewed before visiting the exhibition (first section), and also the level of enjoyment of the virtual visit, considering different general aspects (such as the way the themes were presented, second section) and technical aspects (the functioning of the audio, the visual quality, etc., third section). Since the questions, for the first and second sections, were directly related to the steps of the exhibition path, the obtained answers allowed us to assess how effective the virtual visit was and whether there might be weaknesses in this approach, to possibly improve it. The end-of-course questionnaire is reported in the Appendix.

The data acquired through the three questionnaires have been processed with a spreadsheet and reported in the graphs of Results section.

Results

The collaboration between the researchers and the MSN staff allowed the exhibition to be set up and then visited by the public and schools, despite the adversity of the moment, both in presence and through the virtual access.

In the following, we will briefly present the two main results of this collaboration: how the exhibition developed, focusing on some of the exhibits, and the most interesting results from the analysis of the answers to the questionnaires proposed in the form of online quizzes.

The exhibition

The exhibition was organized as an experiential path arranged in a way that, starting from the first step, continued through the entire Gallery of Cetaceans for a total of 11 conceptual steps, touching on different topics. For each step, one or sometimes more exhibits were set up. In Table 1 an outline of the path and the relative topics covered in it is shown.

First part: Starting from the Mediterranean Sea

Visitors entering the Gallery of Cetaceans, where the exhibition was located, were forced to share their point of view with that of some sea animals, literally immersed in a sea of plastic (Fig. 1a). The contrast between the marine litter hanging from the ceiling and the beauty of the gallery environment and of the life-size reproductions of marine animals made the impact with the surrounding garbage quite disturbing, eliciting the search of explanations. In the first part of the exhibition (step 1), devoted to producing a strong visual and emotional impact, there were also two artistic representations of a humanity overwhelmed by plastic (Fig. 1b and 1c), flanked by the "My Own Waste" exhibit, which displayed the amount of plastic we throw away every month (step 2, Fig. 1S in Appendix).

Particular attention was paid to the situation of the Mediterranean Sea, the largest and deepest enclosed sea in the world and one of the 25 centres of biodiversity on a planetary scale, and where 7% of the plastics floating in all the world's ocean and seas is concentrated, with respect to a surface equal to about 1% of all saltwater (data from the BlueMed Pilot Action site: http://www.bluemed-initiative.eu/pilot-action-on-a-healthy-plastic-free-mediterranean-sea/, accessed 21 November 2021).

The results of the most recent research on the situation in the Mediterranean Sea were reported in panels (step 3), which illustrated the different types of marine litter present in our sea and along our coasts and drew a global picture of the possible consequences for the environment. In the same area, a sandbox was set up to reproduce the highly plastic-polluted appearance of one of the coastal protected areas near the nearby town Pisa. The aim of this exhibit was to show that these problems do not only concern distant areas frequently talked about in the media (such as the trash vortex in the Pacific or in other oceanic areas), but also places that are closer to the visitor, such as the nearby beaches even in protected areas. This sand box was originally intended to be interactive for visitors, especially for students, allowing them to extract and cat-

Table 1. The 11 conceptual steps of the exhibition path, with the exhibits presented and their short descriptions.

Experiential path' step number and Topic	Exhibit name	Description
1. The problem of plastic in the marine environment	**Med Trash Vortex** **Lorenzo Possenti plastic sculptures**	The plastic rubbish surrounding dolphin and whale models reproduce a "trash vortex" in the Mediterranean (Fig. 1a) The "Vitruvian Man" and the "Birth of Venus" have been reinterpreted as icons of plastic becoming part of the human being in the present and future generation. (Fig. 1b)
2. Knowledge/awareness of the amount of plastic items used and thrown away on a personal/ family level	**My own waste**	All the plastic rubbish produced by a family in a month has been recorded and put on display.
3. Study methods for the quantification and distribution of plastic in the marine environment	**Off-season beaches**	The reproduction of a small area of sandy beach in the natural reserve of San Rossore - Migliarino - Massaciuccoli (Pisa, Tuscany) evidences the abundance of stranded marine litter.
4. Problems related to the degradation/fragmentation of plastics and knowledge of the degradation times of plastics in the marine environment	**A piece of plastic is forever**	A simple wooden didactic toy makes people discover the time of permanence in the natural environment of plastic objects.
5. Effects of plastics on marine wildlife	**Different size, different danger** **Indigestible plastics**	A simple wooden didactic toy makes people discover the relation between the size of the plastic debris and the size of the animals they can damage. The plastic frequently found inside the stomach of marine mammals, sea birds, turtles and fishes is here symbolically represented by rubbish bags placed inside some of the cetacean skeletons of the gallery. The possible injuries to animals are explained.
6. The main vectors of plastic transport at sea	**The ways of waste**	The section of the gallery where "river dolphins" are on display becomes the place to develop the theme of rivers as the main supplier of plastic litter.
7. The different types of plastics (polymers) that make up the different objects	**On the side of plastic**	The different polymers and their peculiar properties are the subject of this more detailed exhibit (deepening) meant to reiterate the concept that plastic itself is a valid material but we must learn to manage it correctly.
8. Knowledge of the correct disposal of objects by category	**A Cubic Meter of milk bottles.**	Two metal net cages filled with empty milk bottles and with the same bottles flattened is the occasion to explain the correct way to flatten a plastic bottle and to make people visualize what a huge quantity of plastic waste each of us produce.
9. Knowledge of recovery and recycling methods for used plastics	**Plastic as a resource**	Several objects made in recycled plastic represent the final result of the industrial process illustrated by a video, realized by Revet to show the complete process to transform an empty yogurt jar into a bench.
10. How to sort plastics properly: label knowledge	**Where should I throw it?**	A simple wooden didactic toy, resembling an abacus, explains the meaning of some of the many labels related to sorting and recycling present on plastic packages.
11. Awareness that the real problem is not plastic, but its incorrect management, from excessive production, marketing and consumption to its disposal	**Pinocchio and Plasticchio** **Not only plastic** **Coronavirus pollution (or the waste of the future)**	A plastic-waste made puppet called Plasticchio joins the wooden Pinocchio inside the whale belly to suggest to people that plastic is not the best material for everything. A still life painting with poppies is compared to a drawing of plastic bottles to hint that natural objects and materials are generally more artistic and evocative than plastics. The increased use of disposable objects is presented as another of the many problems caused by the Coronavirus pandemic.

alogue the plastic finds, using the same methodology and protocol used by the researchers.

The two exhibits "A Piece of Plastic Is Forever" (Fig. 2a) and "Different Size, Different Danger" (Fig. 2b) helped visitors to grasp important concepts about features of plastic dispersed in the marine environment. The former dealt with the degradation time of plastic objects (step 4), asking visitors to put several different everyday plastic objects on a 1-meter-long ruler, based on the time they could remain unaltered in the environment. Visitors discovered, often with surprise, the long time needed to decompose the polymeric materials. Moreover, here they discovered also that even the latest generation of polymers, specifically designed to have faster decomposition times under industrial conditions (compostable materials, improperly marketed as 'biodegradable') represents an environmental problem if not properly disposed. In fact, it has been observed that the marine environment hinders the fast decomposition of compostable material, in a rather complex process in which more aspects play a role simultaneously (UNEP, 2015).

The second exhibit (Different Size, Different Danger) was dedicated to the danger that plastic in the sea represented for marine animals (step 5). The damage can be both physical and chemical and, for different animal sizes, depends on the dimension of the plastic objects, too. The exhibit included an interactive game in which visitors had to associate the different rubbish size, represented on a 1-meter ruler, to the different marine animals, encouraging reflection about this issue. An explanatory panel addressed the different dangers due to the interaction between plastics and marine organisms, namely ingestion and entanglement, which could even lead to death of the marine fauna. The former is the ingestion of macro- or micro- plastics which are confused with possible food, or the ingestion of micro- and nano- plastics by filter-feeding animals; moreover, ingested plastics can contain absorbed toxic pollutants (Persistent Organic Pollutants, POPs) with the subsequent release within the organism itself and accumulation in its living tissues. The latter happens when objects such as fishing nets or nets for mussel farming, fishing lines, or other types of macro plastics, prevent the animals' movements and can cause asphyxiation, strangulation, and suffocation, also because these objects are often used by animals as building material for nests and dens.

Due to the health emergency that did not allow visitors to touch the exhibits, the original wooden rulers and blocks - to be assembled to reach the solution - were replaced with other, less interactive exhibits, which showed the questions asked and the solutions at the same time. In order not to completely lose interactivity, they were combined with on-line games-quizzes (see next paragraph).

Second part: "Plastics: Where Is the Problem?"

The exhibition continued along the entire Gallery of Cetaceans, dealing with other fundamental topics, such as: the main vectors of plastics transport at sea (step 6), the different types of plastic and the many properties and qualities of these materials (step 7); the good practices for a proper disposal of plastics and their recycling (steps 8 and 9).

For the step 7, an in-depth video, realized in collaboration with Institute for the Chemistry of OrganoMetal-

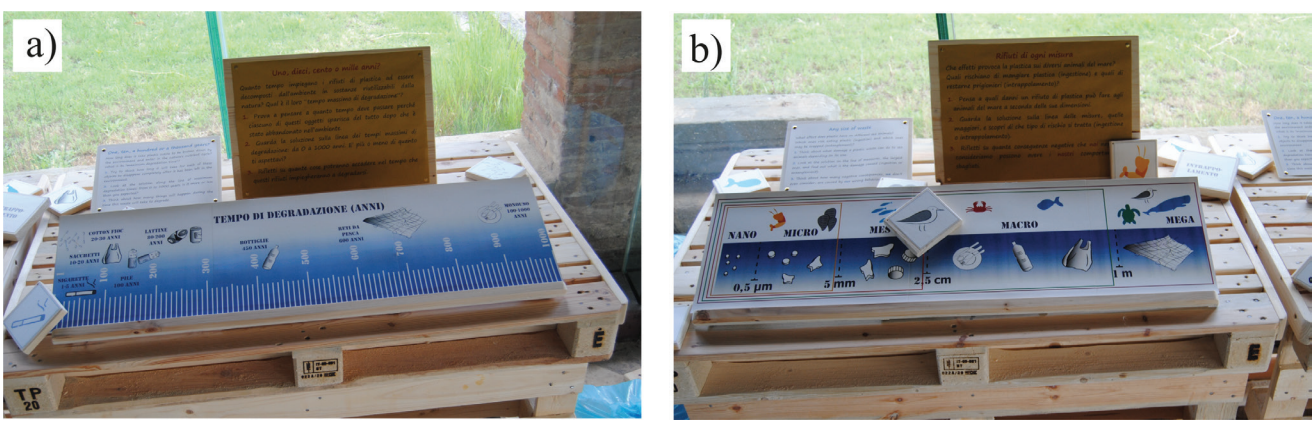

Fig. 2: **a)** A Piece of Plastic Is Forever. This 1-meter-long ruler consists of a timeline from 0 years to 1000 years. Small square boards illustrate the different marine litter (not only plastic): bottles, bags, disposable cutlery, fishing nets, batteries, cans, cigarettes, cotton buds. The game consists of arranging the square boards in the right position in relation to its degradation time. A flap hides the correct solutions of the game.
b) Different Size, Different Danger. This 1-meter-long ruler classifies the plastic into nano-, micro-, meso-, macro- and mega-plastic. Small square boards reproduce different types of marine organisms (turtle, whale, shrimp, seagull, bivalve, small fish, big fish, crab). The interactive game consists of arranging each marine organism on the ruler in the position that corresponds to the plastic dimension that can produce a negative effect on it. For example, microplastic can mostly damage bivalves or shrimps, and megaplastic may cause the entanglement of turtles, big fish or seagulls. But whales, turtles and seabirds can also ingest microplastic while feeding. A flap hides the correct solutions of the game. The figure has some inaccuracies in the definition of nanoplastics, but these will be corrected in the next portable version of the exhibition (nanoplastic < 1 µm; microplastic between 1 µm and 5 mm; mesoplastic between 5 mm and 2,5 cm; macroplastic between 2,5 cm and 1 m; megaplastic > 1 m).

lic Compounds (ICCOM) and Institute for Chemical and Physical Processes (IPCF), both of National Research Council, illustrated the structures and chemical properties of the different polymers, generically known as *plastics*. To emphasize that our point of view was not against plastic itself, there was also a part dedicated to the positive aspects of these materials. Thanks to polymeric materials, in fact, enormous progress has been made in all fields including human health, with prostheses, artificial organs and the most varied medical equipment, down to the simplest surgical gloves.

In steps 8 and 9 we showed how the recycling chain was realized in our local area by the REVET company. The fundamental role played by consumers in influencing the market towards the use of recycled plastic and through market choices, such as using tap water instead of bottled water, was emphasized (Fig. 2S). This exhibit, and the topics it addressed, was also an opportunity to explore prevention as a key aspect of the plastic problem in the environment. Prevention is an essential point and implies an increase in responsibility and concrete actions by the authorities and manufacturers, through the adoption of laws regulating the production, marketing and use of plastics (The Pew Charitable Trusts & SYSTEMIQ, 2020), and also the ban of objects such as plastic cotton buds, single-use items and packaging products, among the 10 most commonly found plastic litter items on beaches (EU SUP Directive, 2019). For more effective prevention, therefore, action must be taken right from the design phase of the object, clearly reducing/eliminating as much as possible those destined for single use, but also designing objects in such a way that they can be more easily recycled and, even better, reused, favouring the circular economy (UNEP, 2018; 2021). As regards prevention, we also emphasised the aspect of individual awareness, which affected above all the choices of consumption and disposal of the objects used. The next exhibit (step 10), in fact, provided indications for correct waste disposal, and based on the knowledge of the different symbols printed on packaging.

The theme of the reduction of production and use of plastics was the main topic of step 11 exhibits. Here visitors meet the mascot of the exhibition "Plasticchio", a puppet made of waste, created by the artist Possenti to mimic the classic wooden Pinocchio: as in the traditional story, both were hosted in the belly of the whale, more precisely between the ribs of a whale skeleton. Besides the engagement of the younger visitors, the twin characters suggested that materials exist that could be better than plastics. A panel was dedicated to this topic, inviting visitors to consider that in many cases (for example for many single-use plastic items and packaging) plastics could be substituted by other materials. It is essential to understand when and how to use this or that, limiting the consumption of plastics to the real needs and choosing, when possible, to go without it. In this regard, in the last topic of step 11 we took into consideration the huge amount of plastics we were using during the COVID-19 pandemic to produce masks and gloves and disposable packaging, and how these materials were increasingly found in the environment (Eionet Report - ETC/WMGE, 2021).

Evaluation: on-line games/questionnaires analysis

The evaluation of the exhibition's efficacy was carried out by administering questionnaires to students. The examined sample was formed by 69 students who visited the exhibition virtually, within the project "Nautici in Blu" carried out by the NGO MAREVIVO (https://marevivo.it). During the virtual visit, we administered the questionnaire corresponding to the game-quizzes described before ("A Piece of Plastic Is Forever", Fig. 2a) to these students; moreover, at the end of the virtual visit, they also filled an "end-of-course questionnaire". We also submitted the "A Piece of Plastic Is Forever" questionnaire to a control group, comprising 71 students of the same age (14-18 years) who did not participate in the remote visit. That allowed us to investigate the initial perception and knowledge of the topic by young people of secondary school age (14-18 years in Italy), and whether participation in the virtual visit increased their knowledge and awareness. The results of the games-quizzes are reported in Fig. 3a regarding the problem of the degradation time of plastics.

We note, in Fig. 3a, that the percentages of correct answers are systematically higher for the "Nautici in Blue" students than for the students of the control group. In particular, the differences are very pronounced for the questions concerning degradation time of plastic bottles, fishing nets, and batteries, while the two groups of answers do not differ significantly as regards the degradation time of cigarettes. We hypothesise (but have not checked) that this is because some of the materials considered are mentioned more often in the media than others. Since cigarette remains are among those that frequently appear in first or second place in the rankings of the most numerous marine litters in the marine environment, the relative information about their environmental effects is also more widespread and well known (European Environment Agency, 2021).

The results of the "end-of-course questionnaire" (see Supplementary Material) are reported in Fig. 3b and 3c. The first group of questions was aimed at finding out if the topics addressed in the didactic path were already known by students, and how much (Fig. 3c, concentric circles); the second group investigated the level of satisfaction with the presentation of these different topics throughout the exhibition (Fig. 3c, histograms); the third group explored how effective the virtual mode adopted for the visit was and what the shortcomings were (Fig. 3b.).

Concerning the first questions (Fig. 3c, concentric circles), 88% of the students responded that their awareness of the problem of plastic in the marine environment was high before the visit (step 1 of the exhibition; about 31 % a lot and 57 % very much). On the other hand, only 21% of them (about 17% a lot and 5% very much) knew the scientific methods for monitoring and quantifying plastic

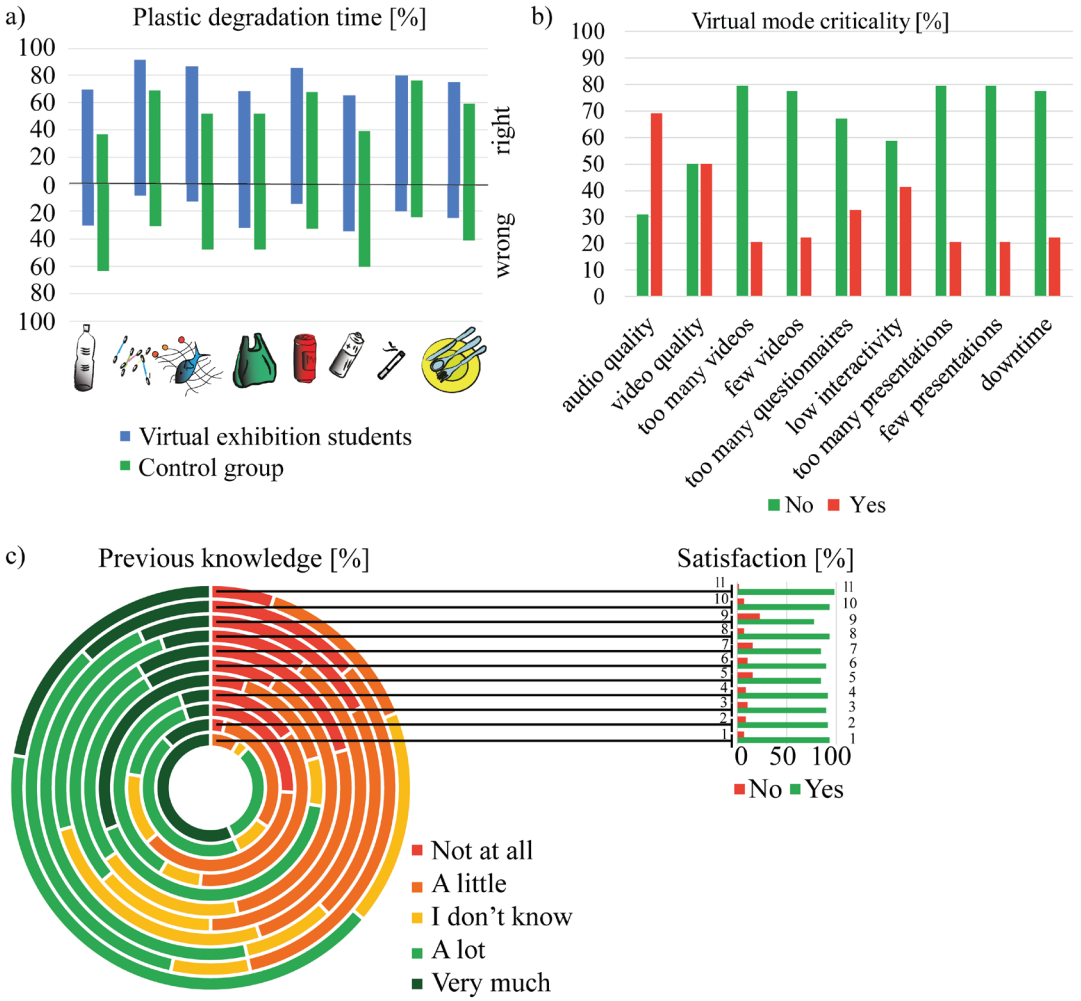

Fig. 3: **a)** Results of the game-quiz "A Piece of Plastic Is Forever". In blue, the answers of students participating in the virtual exhibition visit, and in green, the students of the control group. The X axis indicates the different typology of marine litter, in detail: bottles, cotton buds, fishing nets, bags, cans, batteries, cigarettes and single-use objects. **b)** Results of the third section of the "end-of-course questionnaire". Students' answers report their consideration about the effectiveness of the "virtual mode" adopted for the visit. **c)** Results of the first and second section of the "end-of-course questionnaire". First section answers (previous knowledge of the addressed topics) are reported in the concentric circle chart, while second section answers (level of satisfaction) in the histogram diagram. The 11 investigated topics, connected with the 11 steps of the exhibition path, are the following: 1) marine litter problem; 2) my own waste; 3) monitoring marine litter; 4) plastic degradation time; 5) effect of plastic in marine wildlife; 6) main vectors of plastic transport at sea; 7) different types of plastics (polymers); 8) correct disposal of objects by category; 9) recycling methods for used plastics; 10) waste label knowledge; 11) the real problem is not plastic, but its incorrect management.

accumulations in the sea and on beaches (step 3). The degradation time of polymeric objects in the marine environment (step 4), which was addressed and explained in detail during the visit to the exhibition, was previously unknown for most of them (about 16% Not at all, about 36% a little and about 7% I don't know). This fact is even more interesting when compared with the answers given by the students to the questions, related to these issues, obtained through the ruler games-quizzes (Fig. 3a), and confirms that the virtual visit has achieved the purpose we had set, and that the student level of knowledge of these topics has significantly increased after visiting the exhibition.

Another aspect of plastic pollution that was little known to the students, prior to their participation in the virtual visit, was related to the mechanisms of introduction and transport of marine litter into the sea (step 6). This is a subject that has only recently begun to be discussed in the mass media, finally drawing attention to the role of rivers and waterways in general, in tracing the routes of waste from land to sea. The knowledge declared by the students was quite low about the existence of different types of "plastic" (different polymers, step 7; about 21% Not at all, about 29% A little and about 14% I don't know). Moreover, they showed very little knowledge on the proper disposal of objects (step 8; about 10% Not at all, about 34% A little, about 26% I don't know), a worrying sign that these concepts were not taught enough either at school or family level. Finally, when asked if they were aware of the human role as cause of the problem of plastic in the environment (step 11), students answered with a predominance of "A lot" (about 41%) and "Very much" (about 22%).

Overall, the items that received the highest percentage of positive responses were related to the general themes of the exhibition: awareness of marine litter (step 1), its relevance in the ocean (step 5), and the human role in plastic pollution (step 11), meaning that students had opportunities to reflect on these issues, individually or in groups. On the other hand, the lowest percentages of positive answers were related to the questions that asked for a deeper knowledge of the problem, which could only be obtained with in-depth work, for example in school.

As regards the results of the second group of questions (Fig. 3c, histogram on the right), students were generally satisfied with the way the topics were presented for all 11 steps of the course. The level of satisfaction for step 3, corresponding to the topic "Study methods for the quantification and distribution of plastic in the marine environment" (Table 1), seemed to be slightly lower (78% of the students). Here there should have been an interactive exhibit, as described before. Probably the lack of such interactive activity made the way of conveying information during this step less engaging than they expected.

Answers collected for the third section of the questionnaire revealed that the students enjoyed the virtual visit very much (Fig. 3b). The highlighted critical points were mainly those related to wireless network connection problems, video (50%) and audio (69%). In this case we verified that the audio and video problems depended on the quality of the connection in home reception and not in emission. From this, it emerges that distance learning tours should preferably be implemented with the class in attendance at school, to guarantee the same good quality of reception to all students. On the other hand, the students considered the visit sufficiently interactive (59%), which represented a considerable success for us, given the difficulties involved.

Students were also asked free-response questions, such as "What would you improve in the exhibition? Or "What impressed you most about the exhibition?". Answers that can be considered, overall, as "positive in any way", were about 67% (some examples: "I wouldn't improve anything"; "It's fine as it is"; "I find it adequate", "I would not change anything", "It was sufficiently comprehensive", "It was very well explained", "Considering the emergency situation we are in I think it is well done", etc….). We considered "positive in any way" only the answers that expressed an appreciation for the exhibition and the virtual tour, as it was proposed to them, without suggesting further changes, while those in which the students gave suggestions to improve the success of the guided tour (increase interactivity, change some video shots on some of the "conceptual steps", add more interactive games, make the path longer to include more detailed explanation etc.) came out at 33%.

Discussion

The exhibition itself and the many collateral activities connected to it (seminars, refresher courses for teachers, online and printed educational material) represent an experience of "ocean literacy" proposed by the MSN, to make visitors aware of the problems associated with the presence and consequences of waste in the in the marine environment. It was set up as a self-explanatory tour, designed to provide visitors with both the most up-to-date, scientifically correct news regarding this topic and, at the same time, the possibility to reason, question and rework their previous knowledge in the light of the newly acquired information. In setting up the route in a Museum of Natural History we thought about the fact that the public would have the possibility to observe what nature has been able to do over millions of years, and what our species has been able to do in only a few decades. Almost provocatively, we decided to do that by defacing a beautiful museum gallery, like that dedicated to the cetaceans, with real garbage accumulated from our own daily and monthly waste.

Unfortunately, due to the COVID restrictions, a part of the exhibition has been modified, and the playful approach that characterized some of the designed exhibits could not be used. However, the virtual visit has proved to be a valid alternative when direct interaction has been impossible.

The present exhibition

The evidence presented in this paper suggests that the students had a true interest in the exhibition topic and demonstrated at least a generic knowledge about plastics pollution issue. At the same time, it was clear that gaps existed in terms of issue-specific awareness and knowledge (Fletcher *et al.*, 2009; Hartley *et al.*, 2015). Considering in detail the "free-response questions", about one third of the answers given by the students suggested how the exhibition could be improved, referring not just to logistic aspects (interactivity, connection problems, etc.) but also to the conceptual part. For example: "I suggest explaining in more detail the method of recovering and recycling plastic" and "I suggest explaining more about how different types of plastic are formed". Both related to what is perhaps the most difficult part of the exhibition, namely the 'physical/chemical' side where the polymer structures and the processes of reuse and recovery were briefly explained. The exhibition focalized on the problems associated with the dispersion of plastics in the environment, and also on possible solutions in terms of prevention, both through better legislation and personal engagement (McKinley & Fletcher, 2012; Pahl *et al.*, 2020). As a result, the technical issues of production, disposal, and recycling of polymeric objects were presented in specific exhibits without using specialized language and avoiding scientifically complex details. The students' suggestions challenged us to develop further materials to explore some of these scientific features in greater depth in a possible next version of the exhibition. Among them, the processes of production, recovery, refilling and reuse or recycling of synthetic polymers, and their effectiveness (Geyer *et al*. 2007; Lau *et al*. 2020), as well as investigating the issues of photo-degradation and fragmentation of

plastics in the marine environment (Andrady, 2011; 2015; 2017; Galgani *et al*., 2014; Cózar *et al*., 2014; Koelmans *et al*., 2015). Certainly, these are among the less known topics to the public, and we think they deserve to be more widely disseminated.

Although several topics touched upon are unfamiliar to almost all the students, the results obtained from the game-quiz seem to indicate that the proposed virtual educational tour could adequately communicate concepts and knowledge. Compared to other virtual exhibitions experienced in the world during the COVID-19 emergency (King *et al.*, 2021; UNESCO, 2021), a strong human connection was realized between the operator and the students visiting online the "Plastics and Us" exhibition. The opportunity to interact - albeit at a distance - with the person in the Cetacean Gallery resembled a bit the distance education implemented in schools during the pandemic period. At the same time, the interesting topic and the novelty of the experience ensured the curiosity and participation of the students.

Whereas audience evaluation has long been well established for traditional museum exhibition, in literature we could not find any instruments to specifically evaluate this kind of virtual tour. The instrument presented in this work, applied to the sample under study and to the control group, gave us useful information both on the content transmission and the audience enjoyment. We are confident that students' answers to the proposed questionnaires, being anonymous and therefore not susceptible to being influenced by the fear of an assessment, were reliable enough. The picture they portrayed indicated a general awareness and sensitivity towards the environment, and probably the will to do something to change things. However, it also showed a very poor knowledge of the real problems and the means to face them (Fletcher *et al.*, 2009; Hartley *et al.*, 2015). The results of the present study suggest that a more adequate information system is needed, both at school level, by introducing specific themes into national teaching indications, and by using information campaigns. It is time to pass from the most striking news (sperm whales beached with their stomachs full of plastic, turtles with their shells deformed by plastic objects, etc.) to deeper concepts. They span among plastics degradation, the different ways in which plastics interact with biota, the effects of their size, the meaning of words such as "bioplastics'' and "compostable plastics'', the use and disposal of objects made of these types of plastics and their degradability in the marine environment, and others.

Suggestions for improvement of future versions of the exhibition

In the present set-up ("pilot" exhibition), some important aspects were probably less thorough than others. Plastic pollution is a complex problem that simultaneously involves economic, social and technological aspects and its solution should engage governments, business corporations, researchers and local communities in a common effort. Possible future versions of the exhibition could deepen other aspects of this problem. Among them there is the need to have a better design of plastic objects (as well as all other types of objects) by taking into account their end of life, in accordance with circular economy premises (Geissdoerfer *et al*., 2017; Crippa *et al*., 2019): "Recycling begins at the end - the 'get rid' stage of a product's lifecycle. The circular economy, however, goes right back to the beginning to prevent waste and pollution from being created in the first place. In the face of our current environmental challenges, recycling won't be enough to overcome the sheer amount of waste we produce." (from: https://ellenmacarthurfoundation.org/articles/recycling-and-the-circular-economy-whats-the-difference). Action must be taken right from the design phase of the object, clearly reducing/eliminating as much as possible those destined for single use, but also designing objects in such a way that they can then be more easily recycled and, even better, reused, favouring the circular economy (UNEP, 2021).

In a possible next edition of the exhibition, the fundamental idea of circular economy should be explored and explained, and this will require the advice of experts in this specific field. Moreover, a next edition of the exhibition should include the interactive exhibits and games that had to be removed in this pilot version due to the COVID 19 emergency ("Plastic and Sustainability", a game based on the concept of the "wheel of fortune" in which the circular economy, the importance of prevention and the concepts of the 5Rs are taken into account; "Watch Where You Throw Me", an interactive game based on knowledge of the labels currently used for waste disposal, which makes use of the *abacus* described in step 10 of Table 1).

Moreover, answering to the requests of some of the students, some in-depth studies related to the technical and scientific difficulties underlying the processes of production, recovery, refilling and reuse of synthetic polymers (Geyer *et al*. 2007; Lau *et al*. 2020) should be presented. Another point raised by the students regards compostable materials and their correct disposal to avoid their dispersion in the Ocean, where their decomposition is delayed by the low temperature and the lack of bacteria and fungi that are added to industrial composting facilities. (Andrady, 2011; 2015; 2017; Galgani *et al*., 2014; Cózar *et al*., 2014; Koelmans *et al*., 2015). Certainly, these are among the less known topics to the public, and we think they deserve to be more widely disseminated.

Conclusions

"Plastic and Us" is an exhibition designed to raise awareness of the problems of accumulating marine litter, starting with the situation "close by", in our case (Italy) the Mediterranean Sea, and specifically the local protected areas (Pelagos Sanctuary). The aim is to bring citizens closer to the problem and promote a reflection about what can be done to improve the situation. The modular set-up of the exhibition, which does not require a great deal of

expense in materials and facilities, made it more easily adaptable, and therefore reproducible in different contexts (museums or other) where there is interest in carrying out a similar educational journey, after adapting it to one's own local/national situation.

Following the indications in Santoro *et al.* (2021) about the "importance of building collaboration amongst governmental, educational, and private institutions to develop ocean literacy activities", we stress that the role of researchers in this kind of project is fundamental (Andrews *et al*., 2005; van Eijck & Roth, 2007; Jensen *et al*., 2008). The exhibition and the accompanying outreach and educational activities were designed with the participation of researchers working on these issues within the Pelagos Sanctuary area, as well as with the support and supervision of chemists from the Institute for Physical and Chemical Processes of the CNR for some of the more technical aspects of plastics. We think that it is fruitful for the community that the researchers have more engagement with citizenship, by making their knowledge in the field available to the public, and by spreading it outside of their working environment, so contributing to the *dissemination* and *education* process of these issues. In our experience, this project represented a way to create synergies and strengthen relationships among associations, researchers, teachers and engaged citizens interested in the environment, education and knowledge sharing. Unfortunately, many of the interactive exhibits were not used due to the COVID 19 emergency. We hope to be able to offer them again in a future version, improved and extended to include further topics. In this regard, in fact, while preparing this manuscript, we have had the opportunity to broaden our knowledge and views, drawing on information from previous studies which have analysed the relative weight of the widespread public awareness of these issues - in terms of effectiveness, concrete spin-offs, behavioural changes etc. -compared to the mere imposition of clear-cut laws by governments. We think that further editions of the exhibition should furtherly deepen these themes, also through a possible debate by the users, because what is valid for one European country is not necessarily always exportable and shareable in another. In addition to political and legislative action, in our opinion it is important to promote awareness of the critical marine environment among citizens, and to make them understand the role of personal behaviour in creating and solving environmental problems, thus reinforcing the already ongoing process of changing social values to promote pro-marine behavioural choices (McKinley & Fletcher, 2012).

In conclusion, we are confident that the exhibition contributed to raising citizen awareness and Ocean Literacy, and that in the coming years we will see the results of the combined efforts of proposals and activities like this one, and the many others developed in different parts of the world.

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APPENDIX

Fig. 1S: My Own Waste. This exhibit, certainly not particularly attractive from an aesthetic point of view, makes us reflect on our uses and consumption, as it shows all the plastic produced by a family in a month.

Fig. 2S: A Cubic Meter of milk bottles. This exhibit helps to visualize the amount of plastic milk bottles that an average family throws away in a relatively short period of time (8 months). Moreover, the comparison of one cubic meter of uncompact bottles with the volume occupied by the same number of compacted bottles shows how to facilitate garbage collecting.

Table 1S. Questions reported in the end-of-course questionnaire “Plastic and Us”.

Plastics and Us questionnary		
Before visiting the "Plastics and Us" exhibition	were you aware of the problem of plastic in the sea?	Not at all,Very little, I don't known, Quite, Very much
	were you aware of how many plastic items we use and throw away in our households?	
	were you aware of the study methods for the quantification and distribution of plastics in the sea?	
	were you aware of the degradation times of plastics?	
	were you aware of the effects that plastics have on marine wildlife and the environment?	
	were you aware of which are the main carriers of plastic in the sea?	
	were you aware of the different types of plastics (polymers) that make up the different objects?	
	were you aware of: how the recovery and recycling of used plastics is done (using the different polymers as much as possible, instead of burning everything in waste to energy plants)?	
	were you aware of the correct way to dispose of objects according to the category they belong to?	
	were you aware of what are the labels to look at (what do they mean) to sort plastics in a correct way?	
	were you aware of the fact that the real problem is not the plastic, but its incorrect management and disposal?	
In your opinion, did the exhibition "Plastics and Us", through the exhibits proposed, present the topics dealt with, and indicated below, in a satisfactory way?	The problem of plastic in the sea	Not at all,Very little, I don't known, Quite, Very much
	The amount of plastic items used and discarded at the household level	
	The study methods for the quantification and distribution of plastics in the sea	
	The degradation times of plastics in the sea	
	The effects of plastics on marine fauna	
	The main vectors of plastic transport in the sea	
	The different types of plastics (polymers) that make up different objects	
	The methods of recovery and recycling of used plastics	
	The correct disposal of objects by category	
	The existence and meaning of labels	
	The problems related to plastic degradation/fragmentation	
	That the real problem is not the plastic, but its incorrect management	
	What would you improve in the Exhibition?	
	What impressed you most about the Exhibition?	
Due to the health emergency, the Exhibition can only be visited in remote mode. What do you think were the critical issues with this mode? (indicate yes or no for each item below)	audio quality	Yes, No
	video quality	
	too many videos	
	few videos	
	too many questionnaires	
	too little interactivity	
	too many presentations	
	few presentations	
	downtime	

A piece of plastic is forever: Marine litter degradation time

How long do you think different types of marine litter take to degrade? Try to answer the following questions and at the end you will find the solutions with a nice ruler to download. Remember, after downloading the ruler, to return to the questionnaire with the back button, and send us your data.
Have fun! (The data collected is anonymous and will be used for research purposes only).

marina.locritani@ingv.it (non condiviso) Cambia account

*Campo obbligatorio

How old are you? *

- from 6 to 10
- from 11 to 13
- from 14 to 18
- more than 18

Are you visiting the exhibition "Plastic and us" at the Museum of Natural History of the University of Pisa in Calci? *

- Yes
- No

Figure3Sa

How long does it take a bottle to degrade? *

- about 1 year
- about 100 years
- about 450 years

How long does it take a cotton bud to degrade? *

- about 1 year
- from 20 to 30 years
- about 450 years

Figure3Sb

How long does it take a fishing net to degrade? *

- about 1 year
- from 20 to 30 years
- about 600 years

How long does it take a plastic bag to degrade? *

- about 15 years
- from 200 to 300 years
- 1000 years

Figure3Sc

How long does it take a can to degrade? *

- about 10 years
- from 80 to 200 years
- about 950 years

How long does it take a battery to degrade? *

- about 35 years
- about 100 years
- 700 to 900 years

Figure3Sd

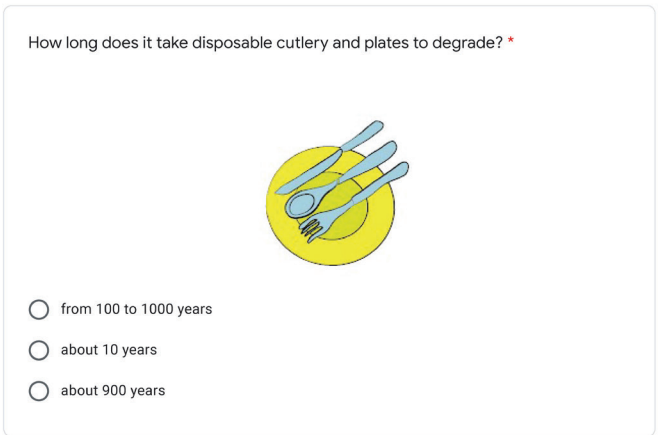

Figure3Se

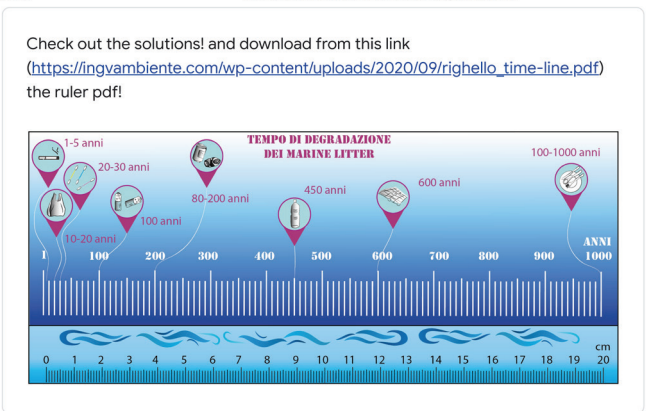

Figure3Sf

Figure 3S. Figures from 3a to 3f are the screenshots of the online questionnaire on degradation time of plastic.