THE LIFE OF THE LOGGERHEAD TURTLE IN THE MEDITERRANEAN SEA:

A CYCLE INTERACTING WITH PLASTICS

Author: Marina Navarro Álvarez

Tutor: Ivan Nadal Latorre
School name: Institut Carles Vallbona
Country: Granollers, Barcelona, Spain

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Summary

Marine pollution is a current environmental problem and has a negative effect on all species that inhabit the planet's waters. Within the framework of an interdisciplinary context, the cycle of the loggerhead sea turtle has been analysed, from its birth to its death, focused on its interaction with plastic waste, including a study of the analysis of its presence on some beaches on the coast. Catalan both in sand and water, on the behaviour of turtles when faced with different shades of plastic, or the analysis of defecated samples.

The results indicate the presence of these residues in the first contacts of the sea turtle since it is born (beach sand and shallow areas close to it). Likewise, samples of plastics ingested by loggerhead turtles have been analysed, with PE being the majority. Finally, it should be noted that the behaviour of captive specimens of the CRAM indicated a greater curiosity towards light colours, these being also the majority in the samples collected.

In short, an open and diverse vision of a current problem, possibly too simplified in its knowledge, is presented here.

Keywords: loggerhead turtle, plastics, biological cycle, pollution, Mediterranean Sea.

Resumen

La contaminación marina es un problema ambiental de actualidad y comporta un efecto negativo en todas las especies que habitan en las aguas del planeta. En el marco de un contexto interdisciplinario, se ha analizado el ciclo de la tortuga boba, desde su nacimiento hasta su muerte, enfocado en su interacción con los residuos plásticos, pasando por un estudio del análisis de presència de éstos en algunas playas de la costa catalana tanto en la arena como el agua, sobre el comportamiento de las tortugas ante diferentes tonalidades de plásticos, o el análisis de muestras defecadas.

Los resultados indican la presencia de estos residuos en los primeros contactos de la tortuga marina desde que nace (arena de la playa y zonas poco profundas próximas a ella). Igualmente, se han podido analizar muestras de plásticos ingeridos por tortugas boba, siendo mayoritario el PE. Finalmente, cabe destacar que el comportamiento de ejemplares en cautividad del CRAM indicó una mayor curiosidad hacia colores claros, siendo éstos también los mayoritarios en las muestras recogidas.

En definitiva, se presenta aquí una visión abierta y diversa de una problemática actual, posiblemente demasiado simplificada en su conocimiento.

Palabras clave: tortuga boba, plásticos, ciclo biológico, contaminación, Mar Mediterráneo.

Acknowledgments

Through these lines I want to highlight the help and support received throughout the completion of this work from certain people or institutions:

First of all, I would like to thank my tutor Ivan Nadal, for having helped and advised me throughout the work, from beginning to end (for all the time used), as well as for having the opportunity to work and delve into an important topic. What is marine pollution like?

Continuing for my parents, for having helped me in everything necessary and for their support throughout this work.

To the Forces Project, and especially Dr. Mònica Martínez López, for the opportunity to work and analyse the samples, especially in the study of the plastic materials in the samples, and for the advice, support and review of the work.

To Irene Antúnez Fernández, Coordinator of the CRAM Education and Training Department, for providing me with the information necessary to carry out the work, and for the different meetings that have been held. And especially for the opportunity to work with the centre's turtles, and thus be able to carry out an ethological study. Also for the support you have given me to carry out the work.

Finally, to all those people who have participated, directly or indirectly.

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Introduction

The waste that reaches the sea increases every year, causing a global problem of pollution in the seas, but have you never considered the harmful effects that plastic can cause in the marine environment? What effects do plastic waste have on marine ecosystems? And where do these plastics end up in the sea? How do these affect food chains and marine biodiversity? Turtles are a bioindicator of the health of the seas, what does this mean? Does ingesting plastics have a negative consequence for your health? Why do turtles confuse plastics with their food? What shades or colours are you most attracted to? These have been some of the questions initially posed to carry out the work.

On the other hand, and given its extension, it covers different content areas, thus highlighting its interdisciplinary nature:

- **Biology**: central area of the work, since the protagonist is the loggerhead turtle, and where aspects throughout it are explained, as well as the study of its behaviour.
- **Sociology**: carrying out two surveys, the first survey to know the information that the population has about marine ecosystems and especially the loggerhead turtle, and the second to know the use of household waste by the respondents.
- **Environment**: part of the work is the effect of plastic waste on the marine environment, in addition to its behaviour towards waste.
- **Ethology**: part of biology that studies animal behaviour. In this case, about the Center for the Recovery of Marine Animals (CRAM, in Catalan) resident individuals and their interaction with food and plastic samples.
- **Chemistry**: one of the elements studied is plastics. In addition to its classification, an analysis of its chemical composition is carried out to understand it and assess its potential recyclability thanks to the collaboration with the Faculty of Chemistry of the UB.
- **Didactics**: production of materials with the aim of raising awareness about the problem analysed, plastic pollution in the marine environment and the consequences it generates on sea turtles, especially *Caretta caretta*.

The motivation to carry out this work arose in parallel to its interdisciplinary nature. Firstly, for doing water sports and for being a person interested in the marine environment and, in particular, turtles. Next, to understand in greater depth the possible effects of waste in the marine environment, especially on loggerhead turtles (*Caretta caretta*; **Figure 1**), animals resident in the Mediterranean Sea, where plastics that reach the seas can more or less serious physical alterations and even death from different causes ([1],[2],[3]) (**Figure 2**).

[1] Greenpeace: https://archivo-es.greenpeace.org/espana/Global/espana/2016/report/plasticos_en_los_oceanos_LR.pdf
[2] Mariano, T.: https://www.hispanidad.com/publirreportaje/12034850_102.html
[3] Return: https://www.retorna.org/mm/file/Documentacion/Basuraoceanos.pdf

Figure 1. Loggerhead sea turtle infographic.
Source:
https://conserveturtles.org/LoggerheadLifeHistoryPosterSpanish-STC.pdf

Figure 2. Photograph of a loggerhead turtle in a plastic net.
Source:
https://www.nationalgeographic.com.es/comen-de-todo.jpg

Figure 3. Classification of plastics according to the Möbius triangle.
Source:
https://firstgreen.es/articles/Codigos_de_plasticos

Likewise, due to the fact that, as a result of the previous bibliographic search on what types of plastics affect these animals the most according to the Möbius triangle ([4],[5]) (**Figure 3**), it has been found that the reference organisation for animal conservation marine animals in Catalonia, the Center for the Recovery of Marine Animals (CRAM, in Catalan) only has two publications on the plastics present in turtle faeces ([6],[7]) with a classification that does not relate them to the Möbius triangle and, therefore, to recycling. (closer to the consumer). Other lines of work related to turtles and plastics focus more on the effects of trawl ([8]) and drift nets ([9]), or the implementation of an awareness project for the recovery of sea turtles ([10]), among others (**Figure 4**).

Figure 4. Screenshot of the CRAM (research and conservation projects) website.
Source:
https://cram.org/investigacion-y-conservacion/

Figure 5. Campaign to clean up seas and oceans.
Source:
https://www.ttandem.com/media/world-ocean-day-5.jpg

Figure 6. Plastic waste coexists with marine organisms.
Source:
https://www.lamoncloa.gob.es/prensa/transicion-ecologica/contaminacion-plasticos.jpg

[4] Aquae Foundation. Types of plastics: https://www.fundacionaquae.org/wiki/tipos-de-plasticos/
[5] Green ecology: https://www.ecologiaverde.com/tipos-de-plasticos-1732.html
[6] Study of the presence of plastics in turtle faeces (2020): https://cram.org/wp-content/2021informe.pdf
[7] Study of the presence of plastics in turtle faeces (2021): https://cram.org/wp-content/2022/INFORME.pdf
[8] Reducing accidental capture of sea turtles in trawl nets: sea turtle exclusion devices: https://cram.org/investigacion-/tortugas-marinas/
[9] Impact study of the driftnet fishery on threatened species: https://cram.org/investigacion-y-conservacion/estudio-de-impacto-de-la-pesqueria-de-las-redes-de- drifts-on-endangered-species
[10] Fisheries awareness and recovery of sea turtles in Tarragona: https://cram.org/wp-content/uploads/2021/05/INFORME-DE-RESULTADOS_Pleamar-II.pdf

Finally, although there are numerous campaigns (**Figure 5**) to raise awareness about the species studied ([11],[12],[13]) and about marine life ([14],[15],[16],[17]), I considered that they followed a very classic pattern and were unattractive for new generations. That is why they could be improved by adding more multimedia elements and introducing virtual reality (VR).

Background

The term "Marine Waste" includes "any persistent solid of non-natural origin, that is, manufactured, that has been dumped, deposited or abandoned in marine and/or coastal environments" (UNEP, 2009), including materials transported to the environment. marine from terrestrial sources through rivers, sewers, or wind action ([18]).

Nowadays, plastic materials have become omnipresent in our lives and in the environment, leading to serious consequences for biodiversity. Being non-biodegradable, it accumulates for many years, causing a dangerous impact on the planet that affects food chains, incorporating itself into food webs. Plastic floods the most remote places on the planet and accounts for 95% of the waste in the Mediterranean Sea, where its pollution contains the highest density of floating microplastics in its waters ([19]). And they not only contaminate the coasts, but affect all marine fauna. In many cases, animals wrap themselves in plastic and mistake the smaller fragments for food, causing poisoning and death ([20]) (**Figure 6**).

Loggerhead sea turtles (*Caretta caretta*) are reptiles that are found in the warm seas and oceans of the planet, specifically in the Atlantic, Pacific, Indian and Mediterranean Seas (**Figure 7**). Their bodies are covered in keratinized epidermal scales, with a dark shell. They are omnivorous viviparous animals, without teeth and with a very varied diet ([21]). Like many other species of sea turtles, they face a number of global, regional and local threats, where their worst fear is around human activity, starting with the fact that virtually all loggerhead sea turtle populations are accidental capture in the fishing gear, followed by the impacts of marine pollution, mainly due to plastic waste ([22]).

On the other hand, this work has been carried out in collaboration with the CRAM organisation and the University of Barcelona (UB) within the framework of the FORCES Project.

First of all, I signed up for the advice on the 2023 Baccalaureate Research Project ([23]) directed by CRAM. Different meetings were held (**Figure 8**) to define the development of the work in the areas in which said association could support me.

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[11] IUCN. Marine mammals and turtles of the Mediterranean and Black Sea: https://portals.iucn.org/library/sites/library/files/documents/2012-022-Es.pdf
[12] CRAM: https://cram.org/catalogo-de-epecies/reptiles-marinos/tortugas-marinas/turtle-loggerhead/
[13] Canary Islands Biodiversity: https://www3.gobiernodecanarias.org/ecoescuela/files/formidable /IA_Tortuga_boba.pdf
[14] Penguin Planet: https://www.ttandem.com/blog/campanas-publicitarias-favor-de-la-proteccion-de-los-oceanos/
[15] Pollution of the marine environment. https://www.ecologistsenaccion.org/198899/la-campana-limpiemos-el-mar-recoge-640-kilos-de-cambio-principalmente-de-origen-plastico/
[16] UNEP: https://www.unep.org/es/noticias-y-reportajes/reportajes/campana-mares-limpios
[17] Maritime Rescue: http://www.salvamentomaritimo.es/sala-de-comunicacion/sala-de-prensamareslimpios
[18] MITECO: https://www.miteco.gob.es/es/costas/temas/proteccion-medio-marino/basuras-marinas /default.aspx
[19] National Geographic Editorial Team: https://www.nationalgeographic.es/medio-ambiente/contaminacion-marina
[20] María Esperanza Iñiguez Cantos. UdeAlicante: https://rua.ua.es/dspace/bitstream/10045/92547/1/tesis_maria_esperanza_iniguez_cantos.pdf
[21] CRAM: https://cram.org/catalogo-de-epecies/reptiles-marinos/tortugas-marinas/tortuga-lobaba/
[22] Chelonia Association: https://www.tortugasmarinasespana.org/tortuga-boba/depredadores-y-amenazas/
[23] CRAM: https://cram.org/educacion-y-formacion/activityes-para-escuelas/programa-educativo/asesoramientoTR

Figure 7. Global distribution of the loggerhead turtle.
Source:
https://www3.gobiernodecanarias.org/recursos/IA_Tortuga_boba.pdf

Figure 8. Meeting at the CRAM headquarters to discuss the organisation and options for the project. In this case, regarding the possibility of making an ethogram.

Figure 9. Screenshot of the FORCES - UB Project Web page.
Source:
https://www.ub.edu/cere/forces/llista-projectes

On the other hand, I found out thanks to my tutor that the UB provides a program called Project Forces ([24]) (**Figure 9**) which seeks to help and promote the connection between the different Faculties of the UB and the secondary education centres. When our connection with the program was confirmed, we contacted Mònica Martínez, professor at the Department of Materials Science and Physical Chemistry at the Faculty of Chemistry of the UB. The meetings held had the same purpose as those of the CRAM, allowing us to delve deeper into aspects related to the classification and analysis of plastic samples.

Working hypotheses and research objectives

3.1. Hypothesis

According to the studies, we have a series of related hypotheses. Given the extent of the work, those related to the studies that will be explained later are indicated here. Plastic could pose a significant risk to the planet and its abuse could cause a serious impact. The presence of these materials could be observed on the beaches. Likewise, the granulometry of the beaches could affect the presence of sea turtle nests. The water from the beaches analysed could contain a high presence of plastic materials, which could then be ingested by marine animals. This is why turtles in particular might be more curious about lighter tones. There could be a lot of plastic in the turtles' faeces, and therefore in their habitat. This would generate negative effects for them such as poisoning and even death. The most abundant plastics could be PET (polyethylene terephthalate). There could be several options to reduce the use of plastic, either through measures by companies that use this material, which should replace plastic with other less polluting materials, but also through citizen awareness. Therefore, the creation of educational and informative materials could help reduce the use of plastics.

3.2. Objectives

Likewise, for each of the hypotheses raised above, the corresponding objectives are associated. First, to analyse sea pollution in the areas where turtles live, observing which are the most abundant plastics, as well as their physical characteristics (granulometry, presence of plastics, among others). Second, to assess

[24] FORCES: https://www.ub.edu/cere/forces/el-projecte-forces

the impact caused by plastic and other waste in the marine environment. To do this, the aim is to determine the degree of risk of the waste to marine species and specifically, loggerhead turtles. Also, to check the shades that make the turtles most curious, and relate them to the ingestion of plastics in the samples. Finally, to specify measures that can be taken to avoid or minimise pollution, specifically that caused by plastics. And make a series of informative materials to publicise the problem.

Materials and methods

4.1. Materials used

In the different studies carried out, a series of materials have been used that can be consulted in their entirety at the following link. They are divided into field (TC), laboratory (TL) and study and analysis (RA) materials.

4.2. Methodology

E1: we want to relate the first living space with which turtles could interact with plastics. It can be summarised in two situations: on the one hand, when female turtles go to the beaches to lay their eggs, they encounter a series of physical characteristics, especially the granulometry of the sand, which determines possible nesting (**Figure 10**). Likewise, when the eggs hatch, the hatchlings may encounter microplastics found in the beach sand, which may enter their bodies through accidental ingestion.

Firstly, three beaches were selected, one with the presence of a loggerhead turtle nest (Beach of Sa Riera, in Begur, Gerona) and two others that did not (Beach of Ocata, Masnou, Barcelona; Beach of Tamarit, Tarragona). that were visited. There, a field form was filled out with the location, day and time of the study, description, photograph, granulometry, among others. To determine the granulometric characteristics of the sand of each of them, four samples were collected (**Figure 11**) with the corresponding plastic cylinders (*cores*) arranged in the four corners of a square of 1 m on each side (**Figure 12**).

Figure 10. News of loggerhead turtle egg laying.

Figure 11. Collection of sand samples from one of the beaches.

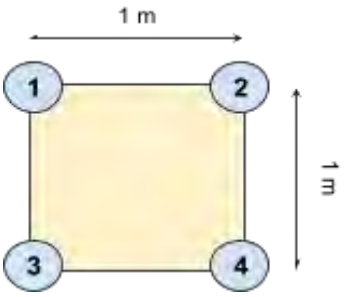

Figure 12. Positional diagram of the "cores" in the sand.

Once in the laboratory, the analysis of the sand samples continued. First, its density was calculated **(Figure 13)**. Subsequently, three granulometric categories were determined, limited by having only two sieves with different pores (<0.3 mm, 0.3-3 mm, >3 mm) (**Figure 14**). Their percentage importance

(partial and total) was determined, data that was collected in a spreadsheet (**Figure 15**). Next, the possible presence of plastics was studied, specifically what could be present in each granulometric fraction. To do this, each sample was placed in a glass jar with fresh water and it was observed if there was any floating material; they were collected (**Figure 16**) and observed under the microscope (**Figure 17**). Using the *Leica Microsystem* application they were scaled to determine their actual size (**Figure 18**). Other fragmented materials that might exist (plants, foraminifera or mineral particles) were discarded. It was transferred to a spreadsheet and the amount of plastics was extrapolated for all the beaches studied thanks to the *Google Maps* ruler tool.

Figure 13. Weighing sand to determine its density.

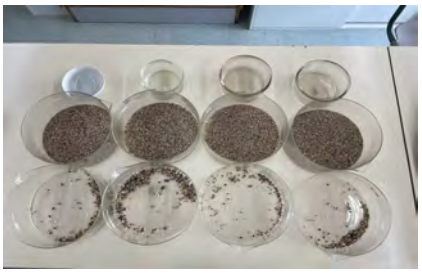

Figure 14. Granulometric blocks obtained.

Figure 15. Creating the spreadsheet.

Figure 16. Collecting samples with tweezers.

Figure 17. Microscope observation.

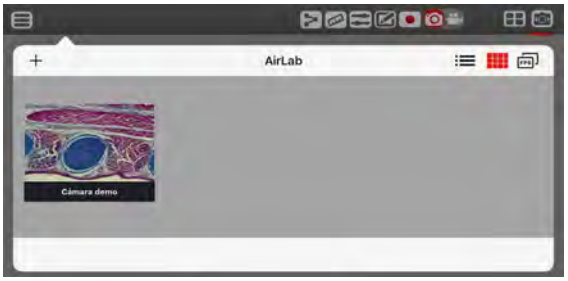

Figure 18. Application used to measure plastic samples.

To conclude this study, and in relation to the educational and awareness-raising objective, with the data obtained and those collected both on the loggerhead turtle nest monitoring page ([25]) and those of the *Green book of the state of the coastal area of Catalonia* ([26]), an interactive map has been created with the help of the *Thinglink* application that can be viewed in a browser, mobile devices and VR glasses.

E2: in this second study we want to relate the second vital space with which the turtles find themselves, that is, when they reach the beach water at birth. There the turtles may or may not encounter plastics. It is the environment in which they will live their entire lives.

Therefore, to begin with, four water samples were taken on each beach analysed, at a distance of 10 m from the beach line, two near the surface, and two at 2 m depth, for 4.23 m (length of the transect) using a

[25] *Caretta* in sight: https://mon.uvic.cat/caretta-a-la-vista/es/historic/
[26] Green book on the status of the coastal area of Catalonia: https://territori.gencat.cat/ca/01_departament/ /llibre_verd/

133.4 micron pore plankton net. These were collected in a plastic container to be subsequently analysed in the laboratory.

In this case, they were placed in a glass jar (**Figures 19 and 20**) and the floating samples were collected (**Figure 21**), following from there the same procedure as in the previous study.

The data has been collected in a spreadsheet for analysis. The exact volume of water was determined, as well as its temperature was measured in situ. In addition, floating plastic samples have been collected from each sample and thus the plastic density for each sample can be calculated. With the data obtained, a specific table of the density of plastics per sample has been created to make a comparison between areas of the Catalan coast.

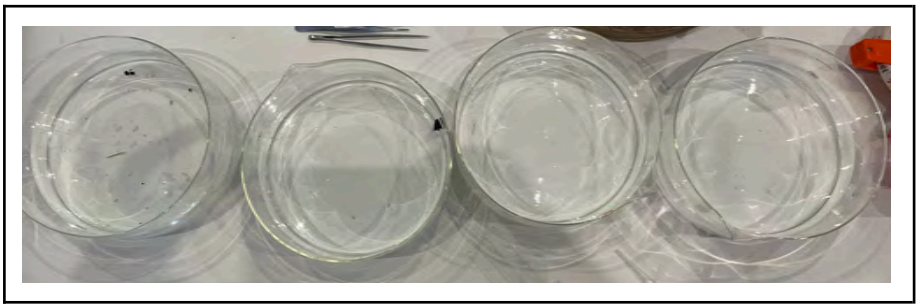

Figure 19. Separation of each water sample according to the collection location.

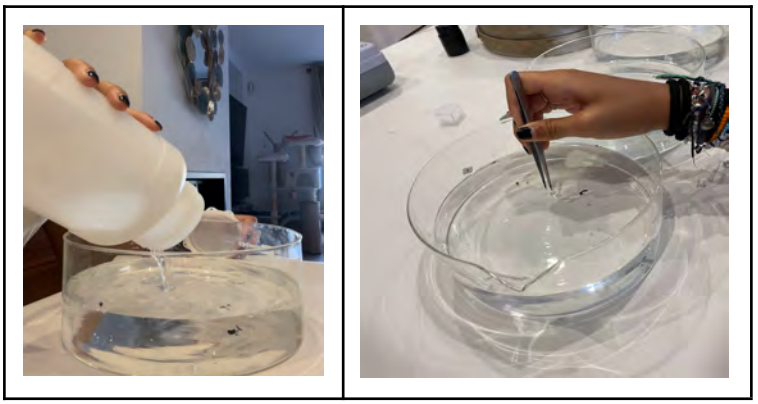

Figure 20(l). Working on the analysis of the collected water samples.

Figure 21(c). Capturing floating samples to be studied under a microscope.

Finally, to complement the information and validate the data obtained in the field, an interview was conducted with a loggerhead turtle professional from the CRAM association, about the return to water of small turtles, and the presence of plastics found both on the beaches and in the water.

E3: we want to relate the adult life of loggerhead turtles to the interaction with plastic waste present in the sea. Two situations arise. On the one hand, their behaviour when faced with plastics of different colours that can be confused (and ingested) as food. Secondly, the type of plastic that turtles most frequently ingest.

Firstly, the samples of ingested and defecated plastics provided by the CRAM were taken to the Faculty of Chemistry of the UB (**Figures 22 and 23**). There, with the use of an IR spectrometer, a total of 52 pieces of plastic from the 18 samples taken at random (problem samples) were analysed to see the IR spectrum graph and identify them. Previously, the spectra of known plastics (control samples) were performed.

Figure 22(i). Procedure for calibrating the spectrograph to begin the analysis.

Figure 23(c). Performing the analysis of one of the samples.

Already in the institute's laboratory, a spreadsheet was created with the name of the sample, an identifying name of each plastic that was in the sample, the weight of each plastic and the type of plastic found in the spectrum. In addition, a data collection was carried out to know the frequency that each type of plastic appears.

The second part of the study was carried out at the CRAM facilities. To study the behaviour (**Figure 24**) in front of coloured plastic with food inside, four drums (blue, red, white and black) with holes (**Figures 25 and 26**) were used where the food was placed inside. white fish, squid and sardines). During 15-minute intervals, every minute, the behaviour of two resident turtles ("Massa Gran" and "4x4") with the drums was studied using the ethogram (start/end time, name of the turtle, water temperature of the pool, mobility and interaction with the drums, mainly) (**Figures 27 and 28**).

Tortuga	
Hora d'inici	
Hora final	
Temperatura	
Contenció	
Objecte	

LLEGENDA

Moviment			Comportament			Objecte	
NR	NL	E	R	A	ES	I	IG
Nada Ràpid	Nadà Lent	Estàtic	Repòs	Esmorteix	Esgarrifa	Interaccions	Ignora

TEMPS	Moviment			Comportament			Objecte		OBSERVACIONS
	NR	NL	E	R	A	ES	I	IG	
00:00 - 00:30									
00:30 - 01:00									
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Cada etograma ha de tindre una durada de 15 minuts, amb intervals de 30 segons.

Figure 24. Screenshot of the ethogram template.

Figure 25(l). Preparing the containers for the study.

Figure 26(c). Distribution of food for the turtles in one of the containers.

Figure 27. Studying behaviour with the turtle "Massa Gran".

Figure 28. Interactions were recorded in an ethogram every minute.

The data obtained was compiled in a spreadsheet where it was analysed.

E4: This study aims to relate the possible consequences of the interaction between plastics and loggerhead turtles using the necropsy technique. Given that they are internal data of the CRAM, a bibliographic search of 4 public necropsies ([27],[28],[29],[30]) of loggerhead turtles has been carried out and the information obtained has been analysed ([29],[30]). The steps studied are: introduction of the procedure, materials used, selection of specimens and performance of the necropsy. To organise the data, a Google questionnaire was carried out and, using the associated spreadsheet, they were organised into four blocks (**Figures 29 and 30**): animal data, external and examination and samples obtained. Finally, the level of importance of the causes of death of loggerhead sea turtles has been studied.

Figure 29(l). Questionnaire created to organise the information from the autopsies analysed.

Figure 30. Spreadsheet of parameters and explanations for performing a necropsy.

E5: Finally, and no less important, this study has been carried out to disseminate, raise awareness and raise awareness of the global problem of marine pollution and the effect on marine animals, create attractive and useful dissemination material for a population as broad as possible, as well as compiling in that material the most important points of the entire work.

To do this, he has created an audiobook (**Figures 31 and 32**) with the *Book Creator application*, a platform that allows adding text, images and audio. It talks about the species, its ecology, the problem of plastics in the marine environment, as well as a compilation of the methodology and the main results

[27] Necropsy 2. https://www.fisheries.noaa.gov/national/marine-life-distress/online-sea-turtle-necropsy-lecture-series
[28] Necropsy 3. https://www.sciencedirect.com/science/article/pii/S0025326X2100374X
[29] Sea turtle necropsy manual. https://georgehbalazs.com/wp-content/uploads/2019/01/turtlmlesp.pdf
[30] Format for necropsies of sea turtles. http://www.iacseaturtle.org/docs/tecnicos/FORMATO.pdf

obtained. Likewise, to be accessible, audios have been created that can be heard in the audiobook. The application also allows self-reading.

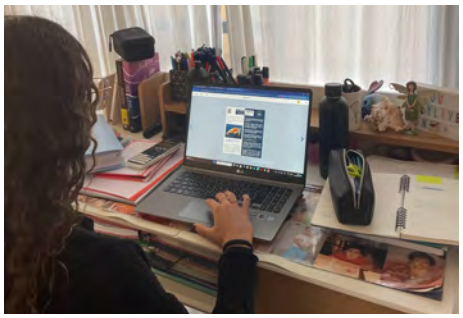

Figure 31(l). Working on the audiobook.

Figure 32(c). Audiobook cover.

Results

Given the extent of the work carried out, the most relevant results are indicated below. Its entirety can be consulted in the original project.

5.1. Analysis and characterization of nests (analysis of beaches; birth→breeding)

The results obtained in relation to the study of plastics found on the beaches studied are contextualised in two calculation documents and the creation of an interactive map.

Firstly we find the characterization of each of the three beaches studied and also their comparison with the entirety of Catalonia. The average volume of the sand collected from the set of samples is 266.85 cm^3, the average mass is 408.87 g and a density of 1.53 g/cm^3. In relation to the characteristics of the beaches studied and their granulometry, the data obtained are the following: starting with the average slope, this is 2.906%, decreasing progressively from north to south. The average granulometry is 1.88 mm (Catalonia average is 0.809 mm), with the same type of evolution (**Figures 33-QR- and 341**). Although the coarse granulometry is greater on the beaches of northern Catalonia, the majority granulometric range is between 0.3 and 3 mm in all of them (**Figures 35 and 36**). Regarding the presence of plastics for each of the beaches, its estimated absolute value ranges between 5 and 58 pl/m^2 of beach with an average of about 27 pl/m^2 (**Figure 37**). Likewise, there is a correlation between the granulometry and the amount of plastics present (r~1) on the beaches studied (**Figure 38**), being directly proportional (the greater the granulometry, the greater the presence of plastics). These values are contextualised in the areas studied.

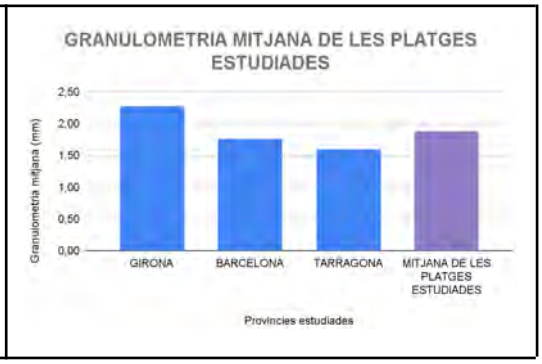

Figure 33(l). QR code summary of beach characterization (in Catalan).

Figure 34(c). Graph of the relative importance of sand grain size on the beaches studied.

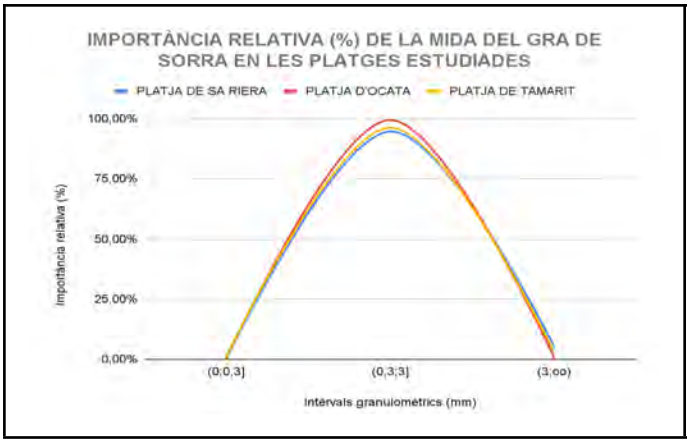

Figure 35. Graph of the relative importance of granulometry in the beaches studied.

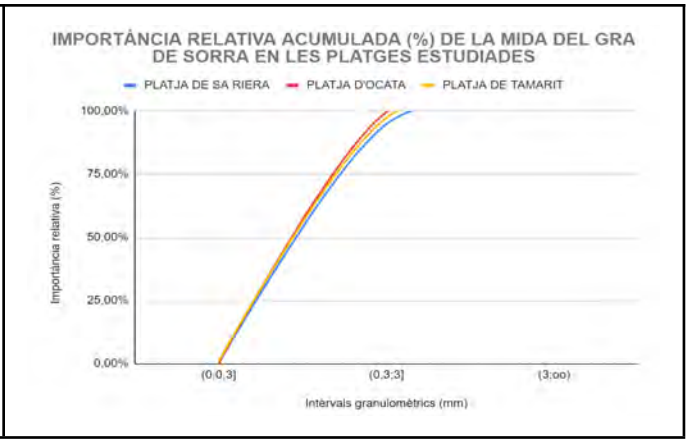

Figure 36. Graph of the accumulated relative importance of the granulometry in the beaches studied.

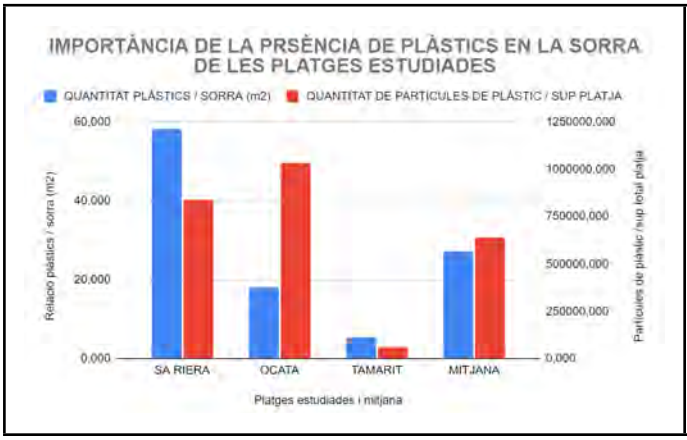

Figure 37. Graph of the importance of the presence of plastics on the beaches studied (m^2 and total).

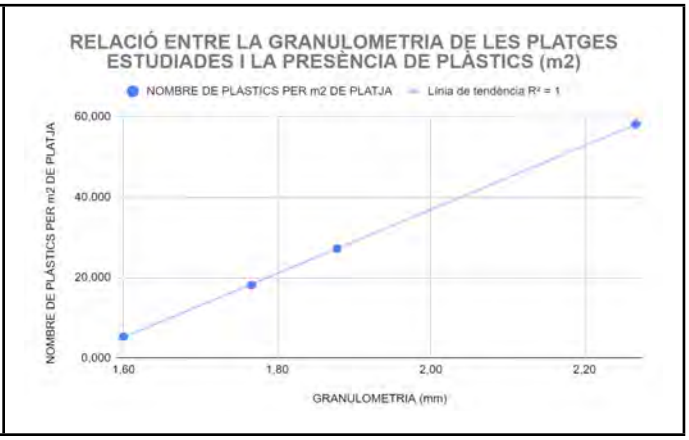

Figure 38. Correlation between the granulometry of the beaches studied and the presence of plastics.

Subsequently, with the data from the Green Book of the Coastal Zone of Catalonia ([31]), a digital book has been made (**Figures 39-QR- and 40**) with the descriptive and granulometric characteristics of three beaches from as many coastal regions of Catalonia. On each sheet you can find its geographical and physical aspects in general to contextualise it (province, region, municipality, slope and a photograph of it). Then there are the granulometric characteristics by non-accumulated and accumulated sand diameter intervals, the statistical parameters of the sample studied (arithmetic mean, mode, standard deviation and coefficient of variation -%-). Finally, a last graph that shows the granulometric data by accumulated intervals of the studied beach.

Finally, with the *Thinglink* application, an interactive map has been created with nest data since 2000, as well as the granulometric characteristics of each coastal area of Catalonia, using data from the *Caretta a la vista* website ([32]), and own granulometric data (**Figures 41-QR- and 42**). Regarding its design, it is a map of Catalonia where three types of information are shown: in blue, the characteristics of egg laying in that locality; in green, the average granulometry of the coastal area studied, with a photo, and in different colours, multimedia information, both own and from bibliographic sources. It is currently in Catalan, Spanish and English. It can be viewed on mobile devices, computers and VR glasses, creating a feeling of immersion when viewed on these (link).

[31] Green book on the status of the coastal area of Catalonia: https://territori.gencat.cat/ca/01_departament/documentacio/
[32] *Caretta in sight:* https://mon.uvic.cat/caretta-a-la-vista/historic/

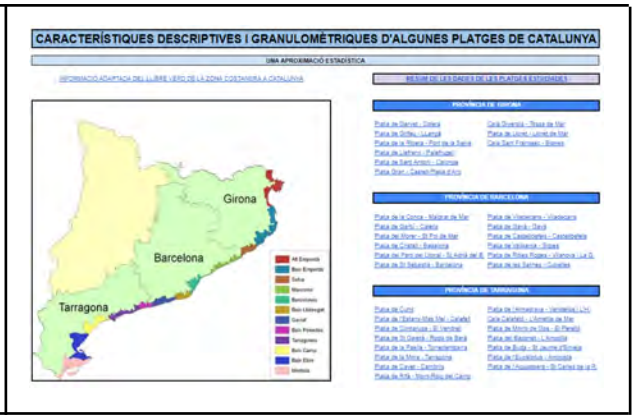

Figure 39(l). QR code characterising some beaches of Catalonia (in Catalan).

Figure 40. Cover of the descriptive book of some beaches in Catalonia.

Figure 41(l). QR code of the interactive map that can also be consulted in VR.

Figure 42(c). Example of how information for each nest is displayed as a pop-up window on the interactive map.

5.2. Birth and return to water (coastal area and beach shore analysis; breeding→juvenile)

General data were collected from each sampling area (date, time and water temperature), and the volume and mass of water collected were calculated for each sample (**Figure 43-QR-**). Also, with the help of the microscope, all the samples floating in the water were analysed, observing whether they were plastics or plant particles. With these data, and the volume of water collected, the density of plastic in the sample (number/ml) was calculated. Overall for the beaches studied (**Figure 44**), this value varies between almost absence to just over 1 pl/mL (Ocata). On the surface this value is greater than in depth.

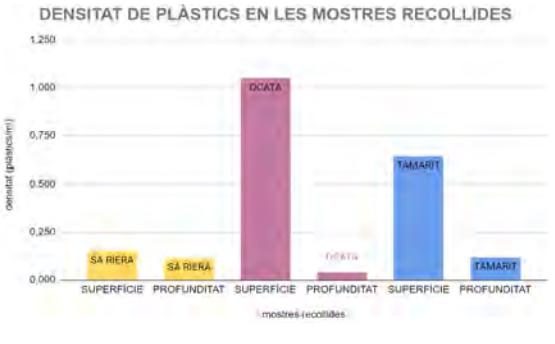

Figure 43(l). QR code of the study of the presence of plastics on the beaches studied.

Figure 44(c). Graph of plastic density in the collected samples.

In reference to plastics and the environment, according to CRAM researchers, it is believed that the former could give off a smell that attracts the animal, not that they confuse them with their food. Likewise, given that turtles are considered bioindicators, through their mortality and population decline it is possible to study whether there is an anthropogenic cause that is causing the problem, such as pollution.

5.3. Behaviour towards plastics and stool study (juvenile→adult)

From the analyses of the CRAM samples observed at the F. of Chemistry of the UB, a table (**Figure 45**), a percentage graph (**Figure 46**), as well as the IR spectra of each sample analysed (control and problem).

From the first it can be seen that the plastic material Polyethylene is the most abundant among the samples collected with 27 of the 52 samples analysed in total, equivalent to 51.9%, while the plastic Polypropylene is the second most abundant with 12 samples and a percentage equivalent of 23.1%. In total, 52 types of plastics have been identified.

TIPUS PLÀSTIC	QUANTITAT	(g)	PERCENTATGE
PET	1	0,151	1,59%
HDPE	1	0,022	0,23%
LDPE	0	0	0,00%
PS	0	0	0,00%
PVC	0	0	0,00%
PE	27	4,142	43,61%
NYLON	1	0,118	1,24%
PP	12	1,978	20,83%
COMPOST	2	1,224	12,89%
PORCINE STOMACH	2	0,262	2,76%
BENZYL COCO	1	0,162	1,71%
COSMETIC	1	1,036	10,91%
GLUE STICK	2	0,232	2,44%
POLYVYNIL	1	0,166	1,75%
ADHESIU	1	0,005	0,05%
TOTAL	**52**	**9,498**	100,00%

Figure 45. Summary table of the set of samples analysed with the IR spectrograph.

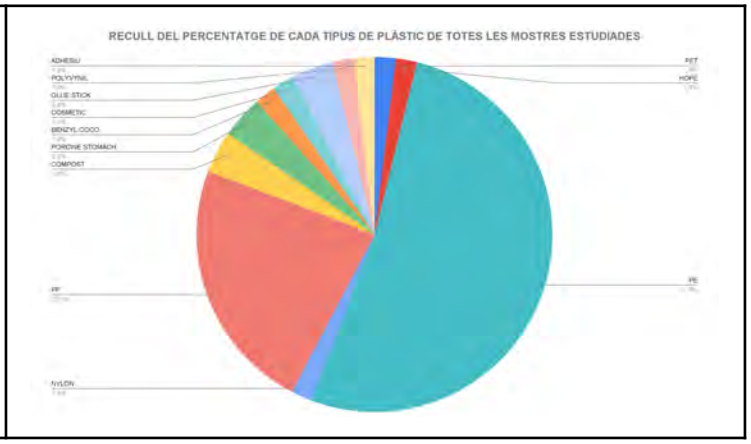

Figure 46. Graph of the percentage of plastic samples studied and identified.

For the second, for each sample analysed with the IR spectrometer, it was possible to observe the type of plastic that resulted from each sample collected from the CRAM. For example, with the sample indicated with the code cc17020, it was observed that it was a PE-type plastic (**Figure 47**), thanks to the analysis of the wavelengths obtained (problem samples) and that relates them to the spectra of samples in which the type of plastic was known (control samples).

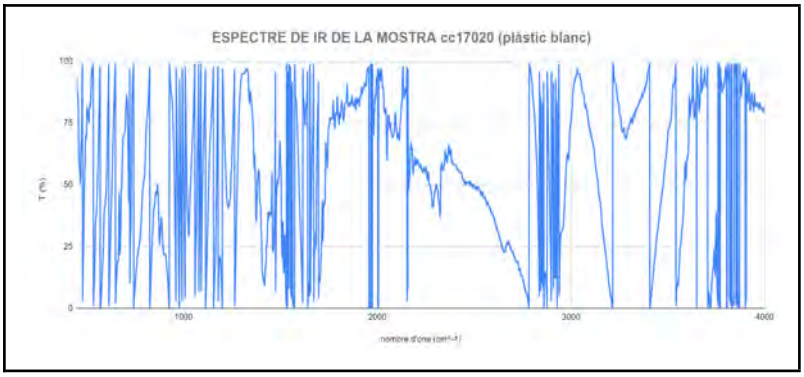

Figure 47. IR spectrum graph of sample cc17020.

Finally, in relation to behaviour, a total of 8 ethograms were made, 4 for the "4x4" turtle and 4 for the "Massa Gran" (**Figure 48**). As a result, we have obtained that the first one did not draw much attention to the drums, although, after approaching, he took the food out of the blue and white drums. On the other hand, the "Massa Gran" approached all the drums, especially the blue and white ones, which were the ones it interacted with the most.

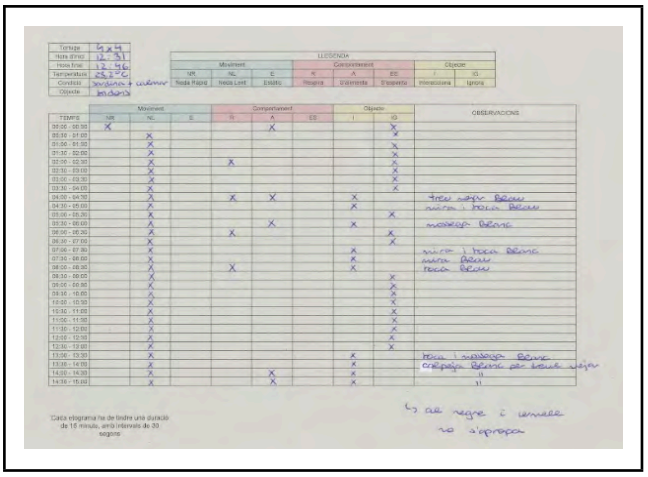

Figure 48. Example of an ethogram of the "4x4" turtle.

5.4. Vital consequences of plastics on turtles (necropsies; adult→elderly)

Based on sample necropsies, discussed above, almost all organs agree with their surface, consistency and colour, as is the case with the lungs. These usually have a pink colour; Even if they have some cuts or abnormalities, that colour does not usually vary in turtles. Also, it has been found that the majority of the turtles studied in the bibliographic sources consulted have presented anomalies in the intestines and stomach, all of them caused by plastic materials.

Furthermore, with data from the CRAM Foundation it has been possible to determine the percentage of deaths of loggerhead sea turtles that have occurred each year, and the cause of death (**Figure 49**). It can be seen that, for example, in 2020 there were 7 loggerhead turtle deaths in the CRAM, of which 4 were due to decompression syndrome, 1 specimen suffered trauma, another cachexia, and the last turtle's cause is unknown. You can also see the trend line, which shows the increase in cases analysed for each cause during the years analysed.

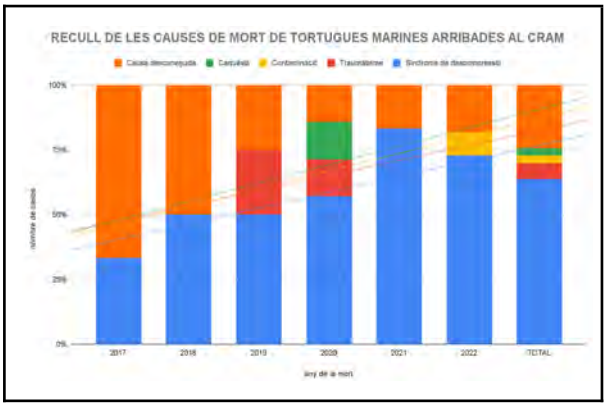

Figure 49. Graph of data collection on the different causes of death of sea turtles at the CRAM.

5.5. Dissemination and awareness material (closing of the circle and synthesis)

The audiobook created presents four large blocks of content:

Cover: title of the work and general data (authorship, tutoring, year and academic centre).

Table of contents: different contents of the audiobook.

Contents: a brief and very visual summary of the main aspects of the work, with a small text on the subject of the content, one or more images and an audio to listen to the text or an extension of the information. Among others, reference is made to the loggerhead turtle (**Figure 50**), marine pollution, plastics as marine waste and the different studies by life stages (**Figure 51**).

Closing: the content ends with thanks to the people and entities that have collaborated in the work, as well as a small reference bibliography on the subject.

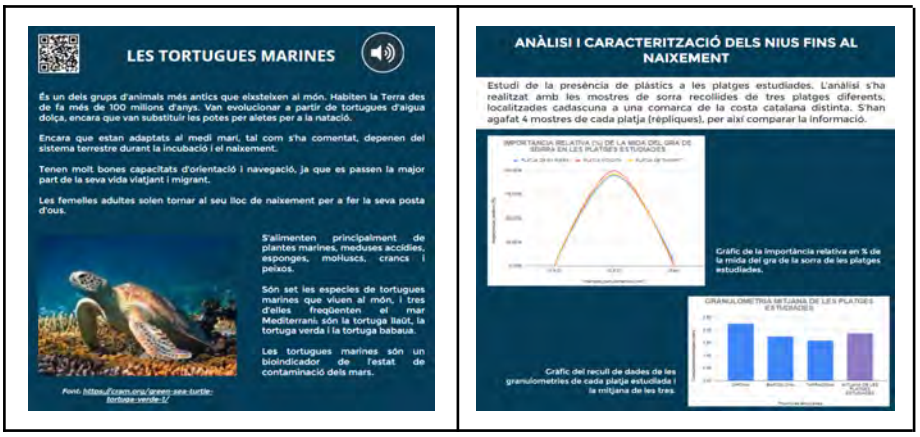

Figure 50(l). Page with information on sea turtles.

Figure 51(c). Page on the study of the analysis and characterization of beaches.

To view and listen to the audiobook online through the *Book Creator* application, you can click on the following links (Catalan / Spanish). It is also intended to be translated into English shortly.

Conclusions

E1. Analysis and characterization of the nests until birth: there are a series of ideal conditions for the presence of turtle nests on Catalan beaches (slope, temperature or the granulometry of the sand, among others). Even so, in recent years nests have been appearing in areas that do not match the "ideal" characteristics (temperature mostly below 27ºC and fine granulometry), possibly due to climate change ([33]). Granulometry plays an important role in observing the presence of plastics on the analysed beaches; larger fragments have been found on beaches with larger grains. The extrapolated quantity has turned out to be important, although the values obtained should be used with caution since the calculation error increases with extrapolation.

E2. Birth and return to the water: the results allow us to affirm that the presence of plastics in the water is less than on the beach, although the smaller ones dominate, while in the water they are a minority and those that have been observed are larger. size. Of the beaches observed, El Masnou is the one with the highest density. As in the previous study, this data must be taken in the context of the work, since it has been considered in the extrapolation that its distribution would be uniform. A proposal for improvement would be to increase the number of replicas used and the surface area studied, both beach and water.

E3. Behaviour towards plastics and faeces analysis: both turtles studied have shown curiosity about the colours blue and white. It is also worth noting that they already "knew" the blue drum, since previous

[33] IRBio UB: http://www.ub.edu/irbio/l-escalfament-global-facilita-la-posta-de-la-tortuga-babaua-la-costa-mediterrania

studies had been carried out with this drum. Therefore, we can affirm that the colour white attracts their attention a little more than the other colours. On the other hand, with the samples of plastic materials coming from the faeces or from the inside of the turtles that reach the CRAM, based on the analysis of the IR spectra of each sample, the most abundant was Polyethylene (PE). This plastic has a large number of uses, such as plastic bags, cables, kitchen plastic, packaging sheets, etc. The results obtained for the first part of the study in relation to the methodology followed do not allow us to accurately extrapolate this behaviour to reality, since for safety reasons for the resident turtles it has not been possible to place plastic fragments mixed with the water in the pools. food.

In relation to the second, the values obtained are contextualised in the samples studied. Due to having a limited time for the spectrographic analysis and due to the number of samples existing in the CRAM, the values could change if the number of samples studied were increased, but it gives an idea of the diversity of plastics existing in the faeces of the turtles that they arrive at the CRAM.

E4. Vital consequences of turtles regarding plastics: from the information collected we can affirm that plastics play an important factor in the vital consequences of turtles. Even so, the study of CRAM data from 2017 to the present indicates that the majority cause of turtle death is decompression syndrome. This disorder is common in turtles that have accidentally been trawled, and when they rise quickly from the bottom they have suffered this decompression syndrome that can cause death.

E6. Dissemination material: regarding the creation of dissemination material, although I consider that dynamic support material has been prepared and suitable for any group, it must be made known so that it is valued. I consider that it may be of interest and complement other existing written materials. Finally, indicate that this work complies with SDGs 4, 13 and 14 of the United Nations (**Figure 52**).

Figure 52. Details of the SDGs that are being worked on in this project with their justification.

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