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Impact of marine debris on sea turtles in mainland France and its overseas territories

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List of acronyms

ADEME: French Environment and Energy Management Agency *(Agence de l'Environnement et de la Maîtrise de l'Énergie)*

ASNNC: Association for the Protection of New Caledonian Nature *(Association pour la Sauvegarde de la Nature Néo-Calédonienne)*

CESTM: Research and Care Center for Sea Turtles *(Centre d'Études et de Soins pour les Tortues Marines)*

CESTMed: Research and Conservation Center for Sea Turtles in the Mediterranean *(Centre d'études et de sauvegarde des Tortues Marines en Méditerranée)*

CMS: Convention on Migratory Species

CNRS-IPHC: French National Scientific Research Center - Hubert Curien Multidisciplinary Institute *(Centre National de la Recherche Scientifique-Institut Pluridisciplinaire Hubert Curien*)

DREAL: French Regional Department of the Environment, Planning and Housing *(Direction Régionale de l'Environnement, de l'Aménagement et du Logement)*

EC: European Community

FAD: Fish Aggregating Device

FAO: Food and Agriculture Organization

FFESSM: French Federation of Undersea Studies and Sports *(Fédération Française d'Études et de Sports Sous-Marins)*

GTMF: Marine Turtle Group France

IOSEA MoU: Indian Ocean and South-East Asia Memorandum of Understanding for the conservation of Marine Turtles (CMS)

ITMNC: New Caledonia Marine Turtle Initiative *(Initiative Tortues Marines de Nouvelle-Calédonie)*

IUCN: International Union for Conservation of Nature

MADE: Mitigating Adverse Ecological impacts of open ocean fisheries *(Program financed by the European Community)*

MNHN: French National Museum of Natural History *(Muséum National d'Histoire naturelle)*

NOAA: National Oceanic and Atmospheric Administration (USA)

ONCFS: French National Hunting and Wildlife Agency *(Office National de la Chasse et de la Faune Sauvage)*

OSPAR: Convention for the Protection of the marine Environment of the North-East Atlantic *(OSPAR stands for "Oslo-Paris")*

OTM: Marine Turtle Observatory *(Observatoire des Tortues Marines)*

RTMAE: East Atlantic Marine Turtle Network *(Réseau Tortues Marines Atlantic Est)*

RTMG: Guadeloupe Marine Turtle Network *(Réseau Tortues Marines Guadeloupe)*

RTMMF: French Mediterranean Marine Turtle Network *(Réseau Tortues Marines de Méditerranée Française)*

SPC: Secretariat of the Pacific Community

SPN: Natural Heritage Department of the

MNHN *(Service du Patrimoine Naturel)*

UNEP: United Nations Environment Program

WIDECAST: Wider Caribbean Sea Turtle Network

Introduction

1. Macro-debris and ocean pollution

1.1. Macro marine debris

Macro marine debris is defined as all material or object built and used by mankind, that is directly or indirectly, voluntarily or involuntarily discarded or abandoned in aquatic ecosystems and ends into the ocean. It is considered that floating or immersed macro-debris is solid and visible to the naked eye (Allsopp 2006, NOAA).

It essentially results from our activities and from what we buy. It may come from the ocean, from commercial or military vessels, pleasure boats or cruise ships, oil tankers or platforms. However, the majority of macro-debris found at sea is continental, brought to the ocean by drainage basins. It comes from beach tourism, harbours and marinas, industrial equipments or public garbage dumps located near the coast. A lot of continental debris is also transported to the ocean by rivers and untreated wastewater. Cyclones, tsunamis, tornadoes, floods and other kinds of powerful climatic hazards also spread macro-debris on the coast and into the ocean. The colonization by human activities of zones liable to flooding and the perspectives offered by climate change predict an increase of this type of pollution (Sheavly & Register 2007).

Figure 1. Accumulation of abandoned waste on a beach in French Guiana (©Kwata association).

1.2. Variety and distribution of macro-debris in the world's oceans

Plastic waste, especially bottles and plastic bags, and waste linked with smoking, are the most common types of macro marine debris in the world. According to a report by UNEP (2009b), they represent 80 percent of the amount of waste collected on the beaches of 12 regional seas (table 1). In Canada, a study shows that 37 percent of the waste present at sea is composed of food packaging (Topping 2000).

Type of waste	No. of items	% of total number of items
Cigarettes and other waste linked with smoking	25 407 457	24.6
Paper bags and plastic bags Lids and bottle caps Food packaging	9 711 238 9 398 977 9 191 575	9.4 9.1 8.9
Plastic plates, spoons and knives Plastic bottles < 2 L	7 426 954 5 684 718	7.2 5.5
Plastic cups Cans Straws, stirrers	4 991 860 4 796 554 4 508 085	4.8 4.6 4.4
Ropes	2 215 329	2.1
Total	103 247 609	80.7

Table 1. List of the ten most abundant types of waste found on the beaches of 12 regional seas around the world (based on combined data from 1989 to 2007 by International Coastal Cleanup, UNEP 2009b).

Macro marine debris is present in all of the world's oceans: near strongly populated regions, but also in isolated regions located far away from any kind of human activity (figure 2).

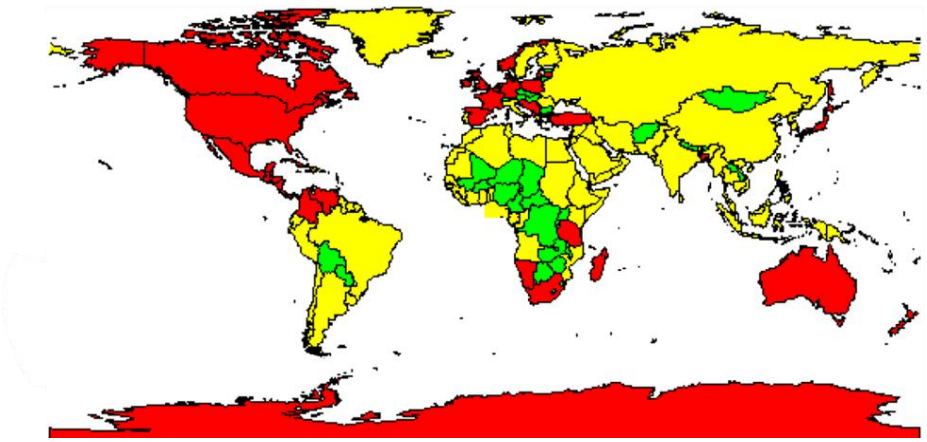

Figure 2. Distribution of macro marine debris in the world's coastal zones (after Topping 2000). In red: confirmed presence of macro marine debris; in yellow: probable presence; in green: little or no macro marine debris (possible emissions via waterways).

Most waste, such as plastic debris, deteriorates very slowly over time and ends up decomposing into small fragments of material that constantly accumulate in the marine environment. Although most of this debris sinks to the ocean floor, this accumulation is conspicuous at the surface of the ocean when currents, tidal cycles, regional topography and winds bring together the floating debris into "ocean vortexes", thus forming gigantic layers of debris (figure 3).

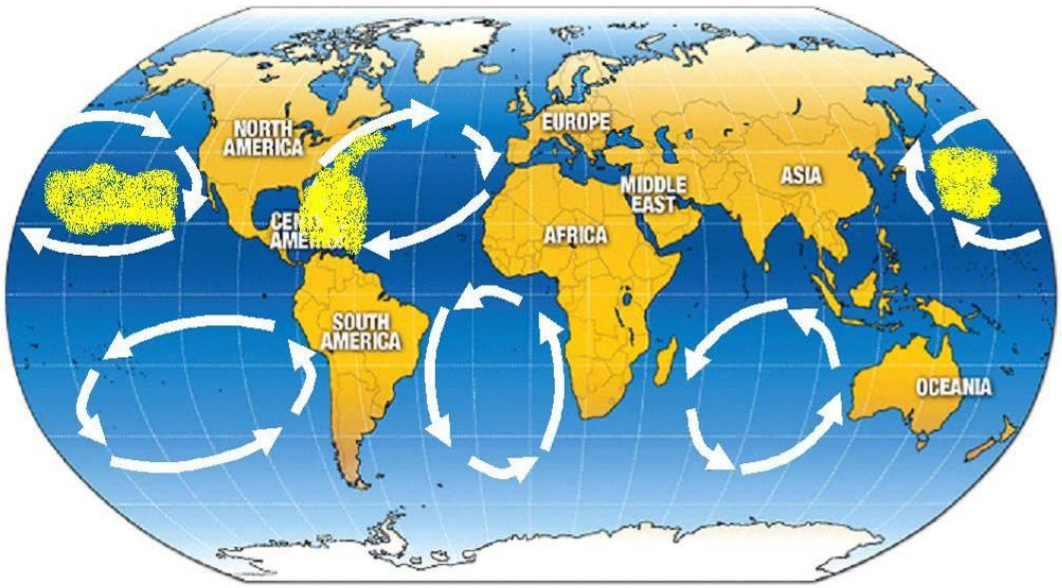

Figure 3. Representation of the layers of plastic debris floating at the surface of the ocean (in yellow) into ocean vortexes (arrows). Map inspired by NOAA Ocean Service Education. http://blogs.ei.columbia.edu/wp-content/uploads/2011/01/Oceanic_gyres-NOAA.png

A patch of plastic debris the size of Europe was discovered in the North Pacific in 1997. This patch is between 10 and 30 meters deep and its density can reach up to 330 000 fragments of plastic per km² (Moore et al. 2001). Another patch of debris was also found in the Atlantic Ocean in 2010, less than 1 000 km away from the american coasts. This patch is as big as France, Belgium and Greece put together and its depth is estimated to be 10 meters. In certain zones, nearly 100 000 fragments of debris were found per km² (Law et al. 2010). According to the "MED Expedition 2010/2013", a scientific, environmental campaign led by researchers from European research laboratories, about 250 billion fragments could be floating at the surface of the Mediterranean Sea (with an average of 115 000 fragments per km²), which corresponds to more than 500 tons of debris (http://www.expeditionmed.eu/fr/wp-content/uploads/2010/11/Expedition-MED-Presentation.pdf).

According to UNEP's estimations (2005), 6.4 million tons of waste reach the ocean every year and each ocean of the world is believed to contain an average of 13 000 fragments of plastic per km². This reflects the breathtakingly high increase of the production of plastic, which passed from 0.5 million tons per year in 1950 to 260 million tons per year in 2008 (Heap 2009). The accumulation of debris in the ocean, as well as the increasing amount of waste that ends into the ocean, foretells an amplification of the phenomenon. Today, it seems vital to lead and encourage actions that aim to reduce the production of waste, especially plastic waste (Allsopp et al. 2006).

1.3. Environmental problems caused by macro marine debris

Not only does macro-debris cause economical and public health problems, but it also causes serious environmental problems (UNEP 2009b). First of all, it threatens coastal and marine biodiversity by carrying invasive species across the oceans (Barnes 2002). Furthermore, in certain zones—especially in ocean garbage patches—the mean mass of plastic per km² can largely exceed the one of plankton, thus exposing organisms to important mecanical friction that may disturb the functioning and composition of present benthic plant and animal communities (Moore et al. 2001).

The multiple next links of the food chain are directly affected by the ingestion of plastic material and the accumulation of toxic components in their organisms (Mato et al. 2001). At least 267 different species, including seals, sea lions, whales, fish and marine turtles, are affected by the ingestion of debris and/or the entanglement in abandoned, lost or discarded fishing gear or pieces of plastic (Laist 1997, Allsopp et al. 2006, Ryan et al. 2009).

2. Marine turtles and macro-debris

2.1. Species, distribution and status of marine turtles

Marine turtles are migratory species whose distribution is worldwide. Among the seven species that have been identified around the world (figure 4), six are present in France's mainland and overseas oceans (table 2): loggerhead turtles (*Caretta caretta*) (b), leatherback turtles (*Dermochelys coriacea*) (a), hawksbill turtles (*Eretmochelys imbricata*) (f), green turtles (*Chelonia mydas*) (e), olive ridley turtles (*Lepidochelys olivacea*) (c) and Kemp's ridley turtles

(*Lepidochelys kempii*) (d). The seventh species, the flatback turtle (*Natator depressus*) (g), is endemic to the North of Australia.

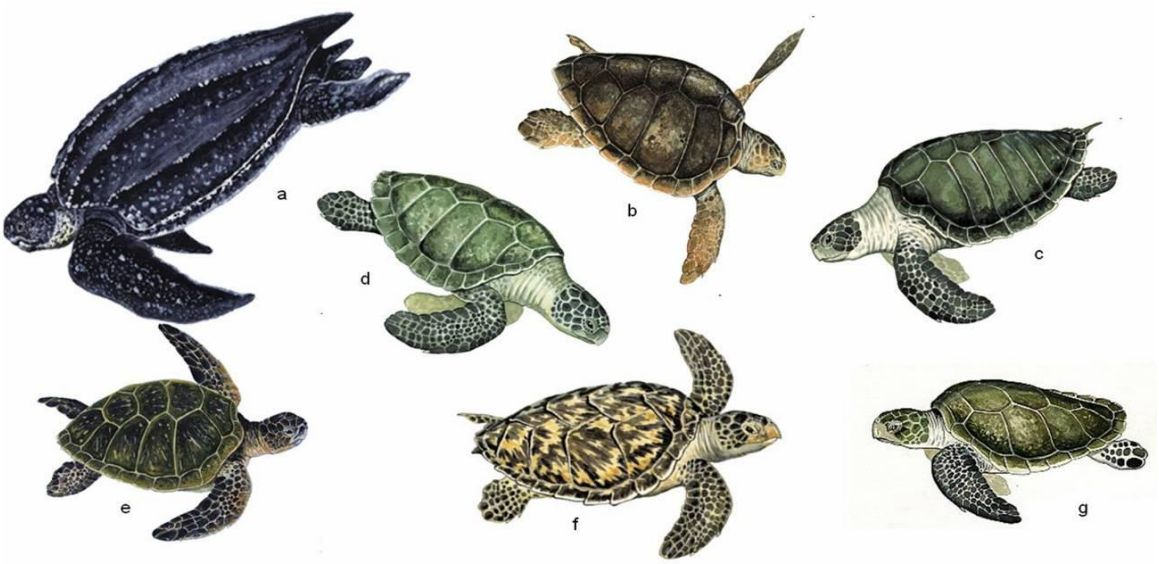

Figure 4. Drawings of the seven existing species of marine turtles
(after http://www.tartanet.it/index.cfm?module = Gallery&page = ImageGallery&ImageGalleryID = 2)

Species	**IUCN status*** *(Red List)*	**Frequented mainland and overseas coastlines** (**in bold:** nesting sites, ****:** nesting sites of worldwide importance)
Hawksbill turtle *Eretmochelys imbricata*	CR	**Guadeloupe, French Guiana (occasional nesting site), Scattered Islands (Juan de Nova only),** Reunion island, **Martinique, Mayotte,** New Caledonia, Polynesia, **St. Barts, St. Martin**
Leatherback turtle *Dermochelys coriacea*	CR	**Guadeloupe, French Guiana**,** Reunion island, **Martinique,** Mayotte, mainland France, Polynesia, **St. Barts, St. Martin,** St. Pierre and Miquelon
Olive ridley turtle *Lepidochelys olivacea*	VU	Clipperton (strandings), Guadeloupe, **French Guiana**,** Reunion island, Martinique, New Caledonia, **Polynesia**
Green turtle *Chelonia mydas*	EN	**Guadeloupe**, French Guiana, Scattered Islands**, Reunion island, **Martinique**, Mayotte**, **mainland France,** New Caledonia**, Polynesia, **St. Barts, St. Martin,** Wallis and Futuna, **St. Pierre and Miquelon (suspected)**
Loggerhead turtle *Caretta caretta*	EN	Guadeloupe, **French Guiana (occasional nesting site),** Scattered Islands, Reunion island, Martinique, Mayotte, mainland France, **New Caledonia**,** Polynesia, St. Barts, St. Pierre and Miquelon (occasional)
Kemp's ridley turtle *Lepidochelys kempii*	CR	Erratic in the entire zone

*International Union for Conservation of Nature
EN: "Endangered"
CR: "Critically endangered"

VU: "Vulnerable"

Table 2. Marine turtle species distribution in France and their international conservation status (IUCN, 2010)

All marine turtle species are on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Leatherback, hawksbill, and Kemp's ridley turtles are listed as "Critically endangered", green and loggerhead turtles appear in the "Endangered" category, and olive ridley turtles are "Vulnerable" (table 2, IUCN 2010).

2.2. French regulations and policies for the conservation of marine turtles and their habitats

France is particularly liable for the conservation of the natural heritage marine turtles represent: it has one of the largest maritime territories in the world and the presence—especially in its overseas territories—of six marine turtle species and nesting sites of major international importance.

At the international level, France has ratified most conventions related to the conservation of species and their habitats, particularly the Convention on the Conservation of Migratory Species of Wild Animals (CMS Convention, 1979), which includes the conservation and restoration of their habitats; the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention, 1982); the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (the Noumea Convention, 1986); the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention, 1990) and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention, 1992). It has also signed the International Convention for the Prevention of Pollution from Ships (MARPOL, 1973).

At the European level, France enforces the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive), which takes *Dermochelys coriacea, Caretta caretta* and *Chelonia mydas* into account. It has also adopted Directive 2008/56/EC (Marine Strategy Framework Directive) of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (commitment by 2020).

At the national level, France has promulgated a specific protection decree, the Decree of 14 October 2005 that determines the list of protected marine turtle species on the national territory, and the terms for the protection of their habitats. It has also initiated two restoration plans in the French West Indies and French Guiana. In order to reinforce the consideration of national conservation efforts, the French Ministry of the Environment revived the "Marine Turtle Group France" (GTMF) in 2008, which succeeded the Marine Turtle Group initiated in 1991. Its secretariat was entrusted to the Natural Heritage Department (SPN) of the French National Museum of Natural History (MNHN). GTMF aims to think about all different aspects of marine turtle management and conservation in France, and to exchange information within the national territory (mainland France and its overseas territories) in connection with international conservation actions. 160 stakeholders are currently a part of GTMF, including several representatives of marine turtle observation networks in mainland France and its overseas territories.

2.3. Impacts of macro-debris on marine turtles

Macro-debris can affect marine turtles in different ways.

The intentional or unintentional ingestion of foreign bodies can provoke internal lesions and obstruct animals' gastrointestinal tracts (Carr 1987, Duguy et al. 1998, Derraik 2002) (figure 5a). Turtles can either mistake waste for preys, or absorb it accidentally at the same time as other nutrients (Hofer 2008). Moreover, the persistence of debris inside the stomach can give animals the impression they are replete, thus leading to malnutrition and sometimes death from starvation (Laist 1987). The partial digestion of pieces of plastic can also lead to chemical contamination, which has harmful consequences on health, even at small concentrations (Derraik 2002, Hofer 2008).

Furthermore, turtles can get entangled in lost, discarded or abandoned fishing gear (or parts of gear)—ghost fishing—resulting in drowning, strangulation or death from injuries due to this gear (figure 5b) (UNEP 2009a).

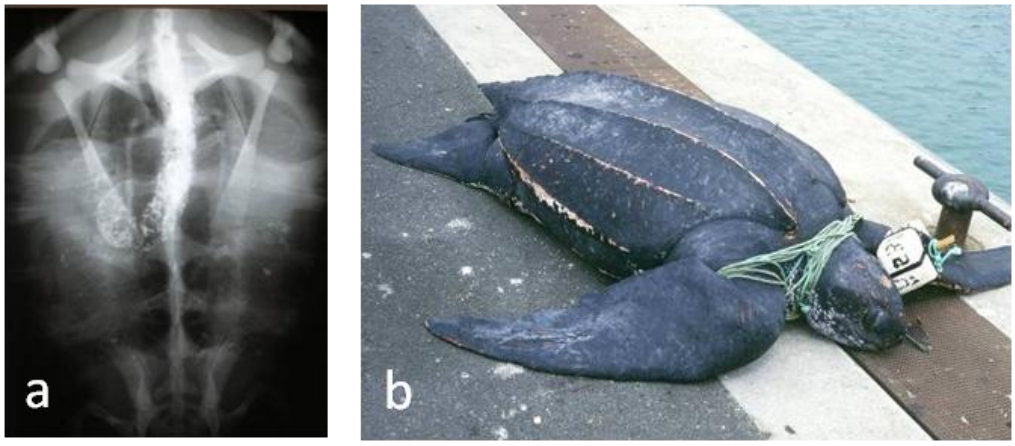

Figure 5. Examples of the impacts macro-debris has on marine turtles in France: a) Waste in the gastrointestinal tract of a green turtle (photograph ©Kélonia) and b) Leatherback turtle entangled in ropes (photograph ©Aquarium de La Rochelle (CESTM)).

Issues and goal of this report

There are relatively few documents about the impact macro-debris has on marine turtles (see 1. in "Results"). Observations are often scattered and available data aren't systematically published. For example, certain publications only mention one or two cases of debris ingestion by marine turtles (Eckert 1988, Allen 1992, Barreiros & Barcelos 2001) and they are often the same species (mainly leatherback, green and loggerhead turtles). In France, information on the subject is usually circulated in gray literature; local observation networks regularly write reports that are distributed by different means (French Ministry of the Environment, websites).

These reports mainly describe the use of the coast by different species of marine turtles, the localization of nesting sites, the number of strandings and where they happened, and the characteristics of collected animals. Little data related to the precise causes of strandings, captures or diseases are available in these documents (Delcroix 2008, Duguy 1987 to 2010, Raigne 2004, Morinière & Dell'Amico 2010, Priac & Petit 2010).

No overview of the impact macro-debris has on marine turtles in France was available in 2009 when France, in the framework of the French *Grenelle de la mer*, opted for several proposals concerning marine habitats (including the proposal of developing, by 2012, a network of marine protected areas covering 10 percent of France's exclusive economic zones), and the attending experts mentionned their concern about macro marine debris.

In order to fill this gap, GTMF undertook the work of summarizing the available data collected by national observation networks and marine turtle care centers, whether published or not. The main goal of this work was to identify the organizations that collect this kind of data on the national territory, and to describe the nature and extent of the impact of macro marine debris observed on marine turtles in mainland France and its overseas territories. Such an assessment will be useful to orient ulterior national actions, but will also be a reference for France when it comes to implementing its international commitments.

Materials and methods

1. Bibliographic research

Bibliographic research was done to put together all of the existing information on macro marine debris, its impact on marine turtles and the measures already implemented to fight against the problems that have been observed. This research was led with help from GTMF members and national and regional experts that have worked on and/or published documents about macro marine debris and/or its impact on marine turtles (Ellik Adler/UNEP; Karen L. Eckert/WIDECAST; Douglas Hykle/IOSEA Marine Turtles; *Mer-Terre* association; *Robin des Bois* association).

About sixty documents (reports, scientific papers and overviews) were thus collected, consulted and filed (see "References").

2. Survey

A survey was led after the bibliographic research; a questionnaire was sent to GTMF members (appendix 1) in order to collect unpublished data and/or photographs. The first questions aim to identify which type of information (files, photos, etc.) each organization owns about the impact of macro-debris on marine turtles in its region. The next questions are more precise; they are about the number of recorded cases, the nature of the problems that are observed, the types of macro-debris involved, the most affected species, the evolution in time of the number of impacted turtles. The form ends with questions about the fight measures that have already been implemented in each specific region and the recommendations for action that may be suggested to limit the recorded problems.

Thirteen organizations returned the completed survey questionnaire (appendix 2). An additional survey was led by means of email exchanges and phone interviews with fifteen people. The information that was transmitted is made up of 8 files (overviews and observation data tables, autopsy reports, publications), 44 photographs (table 3), and complementary information collected during phone interviews. The collected data were then organized to highlight their origin, importance and nature (qualitative, quantitative). Data analysis was restricted by the variability of the quantity and type of elements given by each organization.

Analyses were done with Excel when the quantity of data was sufficient and the data classes were homogeneous.

Organization name	Localization of observations	No. of files transmitted	Types of files transmitted	No. of photos transmitted	Type of information received over the phone
Aquarium La Rochelle (CESTM)	Mainland Atlantic coastline	1	summary of observations	7	-
ONCFS for RTMG	Guadeloupe	1	summary table of observations	0	Observation periods, % of turtles found dead
DREAL/ONCFS	Martinique	0	-	0	-
CNRS/ IPHC	French Guiana	1	publication	7	-
KWATA	French Guiana	-	-	3	-
KELONIA	Reunion island	1	summary table of observations	17	-
CESTMED	Mainland France, Mediterranean coastline	3	Necropsy records	6	Observation periods, No. of collected turtles, % of turtles found dead
RTMMF	Idem	1	summary table of observations	0	species observed, description of cases linked with macro-debris
Aquarium des lagons	New Caledonia	0	-	2	No. of collected turtles, impact of macro-debris, waste involved, species observed
Te mana o te moana	French Polynesia	0	-	0	No. of turtles impacted by macro-debris
Observatoire des tortues marines (Conseil général)	Mayotte	1	slide show summarizing causes of death	2	-

Table 3. Files collected during the present survey.

3. Summary and recommendations

The bibliographic information and the data from the survey were compiled and summarized. The summary was sent to all of the people who had participated in the survey.

Results

1. Contributions of the bibliographic research

1.1. Ingestion of debris

The examination of literature reveals that at least six species of marine turtles are affected by the ingestion of marine debris: olive ridley, leatherback, loggerhead, green, hawksbill and Kemp's ridley turtles. For the last five species, the percentage of individuals that have ingested marine debris can reach up to 87 percent of the total number of autopsied individuals (table 4). Only one publication describes the case of an olive ridley turtle with plastic waste in its stomach (Mascarenhas et al. 2004).

When considering the studies cited in Table 4 in which more than ten turtles of each species had been autopsied, it was noted that waste has been observed in the gastrointestinal tract of 30 percent of Kemp's ridley turtles, 40 percent of leatherback turtles, 46 percent of loggerhead turtles and 51 percent of green turtles. 55 percent of the leatherback turtles collected on the Atlantic coast of mainland France (French departments of Charente-Maritime and Gironde) had fragments of plastic in their gastrointestinal tract (table 4).

Whatever the species, fragments of plastic are the most common type of debris found in turtles' gastrointestinal tracts (table 4). This may be explained by the fact that plastic waste isn't biodegradable and can stay in the animals' gastrointestinal tract for a long time. For example, the time needed to eliminate 50 percent of plastic debris—calculated for three juvenile loggerhead turtles—varies between 6 and 14 days (Brand et al 1999). According to Lutz (1990), all of the ingested plastic waste stays in turtles' bodies for periods ranging from a few days to four months. It is thought that this debris can accumulate with time if turtles swallow it on a regular basis.

The ingestion of marine debris can be intentional, in the case of leatherback turtles for example, which are said to mistake plastic bags for jellyfish, their potential prey (Sadove & Morreale 1989), or unintentional, when turtles swallow waste at the same time as their food, such as has been reported for green and loggerhead turtles (Lutz 1990). It is worth noting that

the ingestion of plastic debris seems to be more important when turtles are starving (Lutz 1990).

Localization of studies	Species	No. of autopsied turtles	% of turtles that have ingested waste	Mortality linked with the ingestion of debris	Type of ingested waste	Authors
Coastline of Floride	Cm Lk Cc	43 7 1	56% 0% 100%	at least 2 turtles	Fragments of plastic, fishing lines, rubber, aluminum foil, tar	Bjorndal et al. 1994
French Mainland Atlantic coastline	Dc	87	55%	NA	Pieces of plastic (94%)	Duguy et al. 2000
Mediterranean (Spain)	Cc	54	79%	NA	Pieces of plastic (75%)	Tomas et al. 2002
Mediterranean (Malta)	NA*	NA	20%	NA	Pieces of plastic, metallic fragments	Gramentz 1988
Coastline of Brazil	Cm Cc Dc	38 10 2	60%	13%	Plastic bags	Bugoni et al. 2001
Coastline of Texas	Cc Cm Ei Lk	88 15 8 104	52% 46% 87% 30%	NA	Mainly pieces of plastic	Plotkin et al. 1990
North Atlantic coastline New York Bright	Dc Cc Cm	33 35 4	30% 8% 25%	NA	NA	Sadove et Morreale 1989
NA (paper)	Dc	408	34%	8.7% of turtles that have ingested waste	Mainly plastic bags	Mrosovsky et al. 2009

Table 4. Results of the main studies on the ingestion of debris by marine turtles in France and other parts of the world. Cm = *Chelonia mydas* (green turtle), Cc = *Caretta caretta* (loggerhead turtle), Dc = *Dermochelys coriacea* (leatherback turtle), Ei = *Eretmochelys imbricata* (hawksbill turtle), Lk = *Lepidochelys kempii* (Kemp's ridley turtle). *NA = Not Available = unavailable data.

In most documented cases, intestinal occlusions or internal lesions cause the death of turtles that have ingested plastic (Bugoni et al. 2001, Tomas et al. 2002).

1.2. Entanglement in fishing gear parts

A great amount of fishing gear is lost, abandoned or discarded at sea every year (table 5). It is estimated in a report that this represents 10 percent (i.e. 640 000 tons) of the total weight of marine debris (Macfayden et al. 2010). There are many reasons as to why fishing gear is abandoned, lost or discarded, including: bad weather; various operational factors concerning fisheries, such as the cost of recovering gear; conflicts between fishing gear owners; illegal, unreported and unregulated fishing; vandalism and theft; difficulty and cost of accessing onshore waste collection infrastructures (Macfayden et al. 2010).

Region	Fishery/types of gear	Estimated losses
North Sea and Northeast Atlantic	Bottom-set gillnet	0.02–0.09% nets lost per boat
Manche et mer du Nord (France)	Gillnets	0.2% à 2.11% loss per boat
Mediterranean	Gillnets	0.05% à 3.2% loss per boat
Gulf of Aden	Pots	approx. 20% loss per boat and per year
United Arab States	Pots	260 000 losses per year in 2002
Indian Ocean (Maldives)	Tuna longlining	3% loss of hooks and leaders
Australia (Queensland)	Blue swimmer crab fishery	35 pots lost per boat and per year
Northeast Pacific	Bristol Bay red king crab fishery	7 000 to 31 000 pots lost per year
Northwest Atlantic	Newfoundland gillnet fisheries	5 000 nets per year
Atlantic (Canada)	Gillnet fisheries	2% nets lost per boat and per year
Gulf of Saint Lawrence	snow crab trap fishery	792 pots lost per year
New England	Lobster fishery	20-30% pots lost per boat and per year
Caribbean Sea	Pot fishing in Guadeloupe	20 000 pots lost per year

Table 5. Estimated fishing gear losses in different parts of the world (Macfayden et al. 2010).

Although it has been proved that marine turtles get entangled in fishing gear (Carr 1987, Matsuoka 2005), it is hard to quantify (Macfayden et al. 2010). However, some numerical data do exist. For example, 7.5 percent of the 400 turtles which were found stranded on the coastline of Texas from 1986 to 1988 were victims of entanglement in fragments of fishing gear (Plotkin et al. 1990)—a review of the literature on this subject reports 55 entanglement cases (Balazs 1985). In Northern Australia, 29 turtles, of which 50 percent were dead, were found in "ghost nets" over a four month period (Roeger 2002). It has been estimated that 20 000 pots are lost annually in Guadeloupe (table 5), as well as the elements that compose their spotting

system (ropes and buoys). The loss of gillnets and numerous leaders (lines and hooks) has also been noted in the French West Indies (E. Delcroix 2011, pers. comm.).

1.3. Fight measures

Curative actions:

The curative actions that are implemented aren't specific to the issue of macro-debris; they correspond to the general measures taken in the framework of collecting marine turtles in difficulty. Depending on the country and available infrastructures, live stranded marine turtles are collected and taken to care centers where they are watched over and treated before being released. Turtles are either treated at the center or taken to a veterinary clinic, especially when additional examinations (x-ray, biochemical analyses, etc.) and/or surgical interventions (stitches, wound cleaning, hook extraction, occlusions, etc.) are necessary. Saving a single turtle has a strong impact on the survival of a population (Lescure 2001)—creating care centers is encouraged internationally (see RAC/SPA 2004 for example).

Documents containing intervention procedures and recommended field-based gestures are circulated for observers where care centers are nonexistent or remote (RAC/SPA 2004, Phelan & Eckert 2006).

Preventive actions:

Preventive actions are led to reduce the quantity of macro-debris that accumulates at sea and on the coast.

At the international level, coastal and ocean cleanup programs are organized on a regular basis, often by associations, volunteers, city councils, etc. In the United States of America, a centralized tool has been created to coordinate and reinforce the efforts carried out in the field of marine debris management (http://www.marinedebris.noaa.gov). Some projects use efficient technical means to collect waste at sea: Rozalia project uses robots and sonars to detect and collect debris lying on the ocean floor; waste is then brought back on land to be sorted and recycled (http://rozaliaproject.blogspot.com/2011/02/announcing-rozalia-projects-trash-tour.html). Other programs specifically aimed to reduce the quantity of discarded fishing gear are also currently being led, e.g. FANTARED Project, DeepNet Project, The High Seas GhostNet Project, or the Fisheries Observer Program for the Pacific Community (SPC) (Brown et al. 2005, Macfadyen et al. 2010). An incentivizing program has been put in

place in Korea for fishermen to recover marine debris and in Hawaii, the fisheries management authority responsible for longline fisheries has placed a device in the harbor to receive and recycle abandoned fishing gear that is willfully collected in the North Pacific fishing zones (FAO 2009).

The organization by NOAA and UNEP of an annual conference in Hawaii was justified by the gravity of the issue of marine debris. This conference allows its participants—international researchers, natural resources managers, policy-makers, representatives of the industry and NGOs—to present the advancement of research, share information on best practices and facilitate the development of international strategies (http://www.5imdc.org).

A scientific and environmental campaign is currently in place in Europe, in the Mediterranean Sea (MED expedition 2010/2013, www.expeditionmed.eu). This campaign mobilizes a team of researchers from a dozen European research laboratories. Its goals are to study the abundance and danger of plastic microfragments that drift and accumulate in the Mediterranean and to alert the population on the harmful effects of plastic in the ocean.

In France, volunteer beach cleanup operations are organized concurrently with public services and city council operations. In 2008, over 7 300 tons of waste (including about 4 000 tons of plastic debris) were picked up on the northern Basque coast by its beach cleanup services (Izquierdo 2009).

Moreover, further to the engagement of the French *Grenelle de l'Environnement* in October 2007, the Operational Waste Committee recommended the definition of a "coordinated plan aimed to reduce macro-debris floating or stranded on rivers, shores, harbors, coasts and the ocean" (*Robin des Bois* association 2009). The workgroup in charge of defining this plan got together six times between December 2008 and April 2009, under the presidency of the *Robin des Bois* association. This plan calls for coordinated and combined actions for a progressive reduction of waste and its management; these actions must be considered as a whole and in a logic of an upstream/downstream link for waste coming from drainage basins and an ocean/land link for maritime waste. Problems of waste originated from fishing and shell fish farming are also addressed (*Robin des Bois* association 2009).

2. Contributions of the survey

2.1. Organizations that collect data

All thirteen organizations that have participated to the survey either collect data on a regular basis or coordinate data collection networks (appendix 2, figure 6). These data are collected in the framework of monitoring and conservation programs, as well as scientific research. Data are collected during nest monitorings, strandings or incidental by-catches, fisheries observation programs, scientific missions and treatments to turtles in difficulty. Among these organizations are a research center, two regional units of ONCFS (Guadeloupe and Martinique), two aquariums (La Rochelle Aquarium (CESTM), *Aquarium des lagons*), two observatories (Kélonia and OTM Mayotte), two associations (CESTMed and *Te Mana o Te Moana*) and an observation network (RTMMF) belonging to the Herpetological Society of France. Other organizations collect data on the national territory.

Five out of these ten organizations have facilities in which to receive and take care of animals in difficulty or perform autopsies: CESTM, Kélonia, CESTMed, *Aquarium des lagons* and *Te mana o te moana*. These care centers usually have precise data on the ingestion of debris and on the number of turtles that most probably were victims of ghost fishing. In order to carry out this survey, we especially asked the people in charge of collecting data for their help.

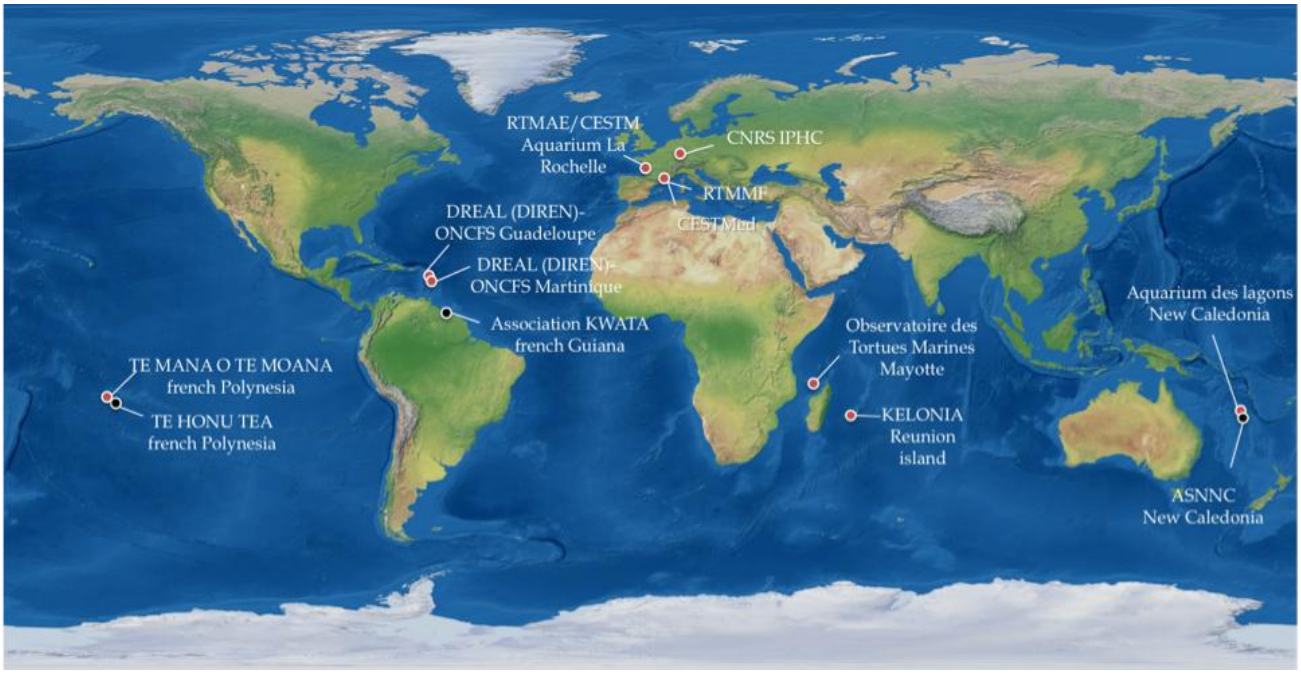

Figure 6. Distribution of the organizations that have participated to the survey. In red: organizations that collect data on macro-debris and marine turtles, in black: organizations that do not collect data.

2.2. Characteristics of collected data

The collected data essentially consist of direct observations of stranded or by-caught turtles, and in some cases, nesting turtles. The rest of the data corresponds to the results either from autopsies performed on dead turtles or from observations made in care centers. In most cases, the people who were contacted collect data thanks to different types of media such as observation forms (9 out of 10) and photographs (8 out of 10). They also write overviews and/or reports on their activities and on the data they collect (8 out of 10) (table 6).

All of these organizations observe live turtles and almost all of them observe dead turtles, but only half of them perform autopsies on a regular basis. When dead turtles were autopsied, it was possible to calculate the ratio of turtles impacted by macro-debris to the number of collected turtles—this is the main index to measure and understand the extent of the problems observed in different French regions.

Name of the participating organizations	Observation localizations	Observation periods	Observation conditions (field or lab*)	Observations on live turtles	Observations on dead turtles	Necropsy	Information media		
							Observation forms	Photos	Reports, overviews
Aquarium La Rochelle (CESTM)	Mainland France, Atlantic coastline	1988-2010	lab	yes	yes	yes	yes	yes	yes
ONCFS/ RTMG	Guadeloupe	2004-2010	field	yes	yes	rare	yes	no	yes
DREAL/ ONCFS	Martinique	2006-2010	field	yes	yes	rare	yes	yes	yes
CNRS/ IPHC	French Guiana	NA	field	yes	no	no	yes	yes	no
Kelonia	Reunion island	2005-2010	lab	yes	yes	yes	yes	yes	yes
CESTMED	Mainland France, Mediterranean coastline	2003-2010	lab	yes	yes	yes	yes	yes	yes
RTMMF	Mainland France, Mediterranean coastline	1999-2010	field	yes	yes	occasional	yes	no	yes
Aquarium des lagons	New Caledonia	2009-2010	lab	yes	yes	yes	no	yes	no
Te mana o te moana	French Polynesia	2004-2010	lab	yes	yes	yes	yes	yes	yes
Observatoire des tortues marines	Mayotte	2004-2011	field	yes	yes	rare	yes	yes	yes

Table 6. Characteristics of the data collected by the ten organizations that have participated to the survey. *labs = care centers, veterinary clinics, laboratories. NA = Not Available.

2.3. Main incriminated debris

Based on the answers to the question: "According to you, do some types of macro-debris cause more problems for marine turtles than others?", the main type of waste is plastic debris, whether hard fragments or plastic bags (figure 7). Small abandoned fishing gear parts including hooks, thin fishing lines and small pieces of nets come next. Nets and other types of large fishing gear come third and one person said it had found cigarette butts in green turtles' stomachs.

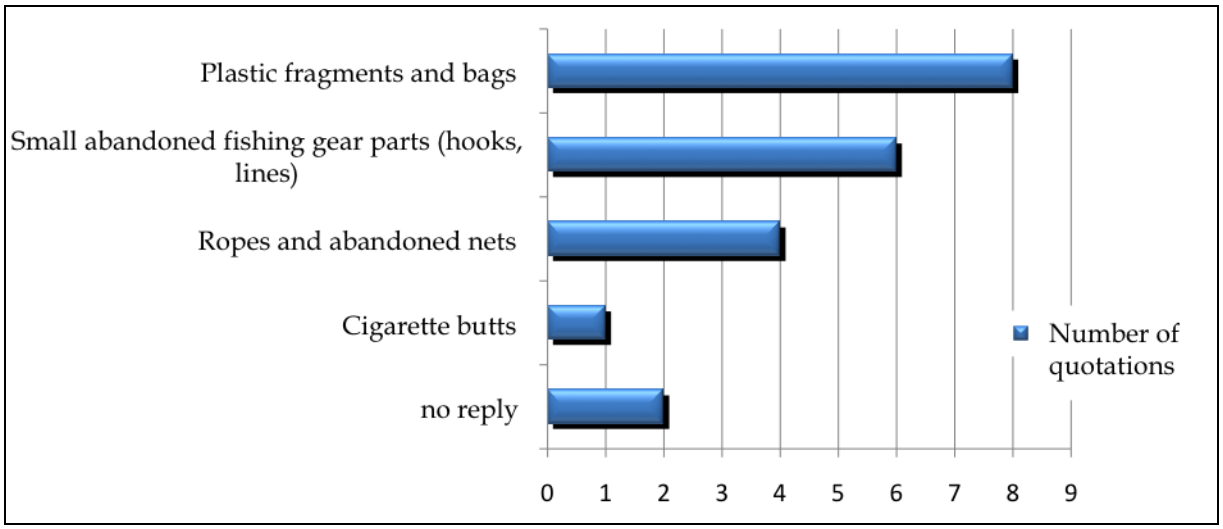

Figure 7. Types of macro-debris that are a problem for marine turtles, according to the participants. Several types of waste were mentionned per answer (19 quotations for 11 answers to the question). Two people did not answer.

2.4. Recurrence and gravity

The answers to the question: "In your center, which are the most recurrent and serious problems linked with macro-debris?" reveal that the main observed problems are intestinal or gastric occlusions, entanglement in lost, abandoned or discarded gear parts (ghost fishing) and difficulties while laying eggs (figure 8). Furthermore, the heaping up of waste can hinder the arrival of turtles to their nesting sites, as well as nest digging and hatchling emergences.

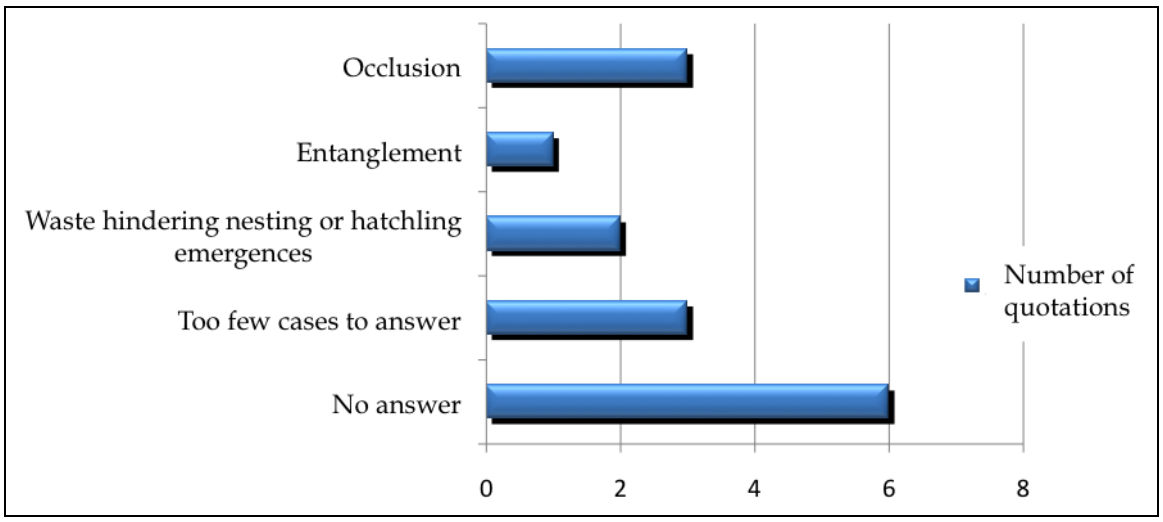

Figure 8. Main problems caused by macro-debris, according to the participants in the survey. Several types of waste were sometimes mentioned per answer (9 quotations for 7 answers to the question). Six people did not answer the question.

2.5. Evolution in time

Based on the increasing number of phone calls inventoried every year, one out of the thirteen participants said to have noticed the number of turtles impacted by macro marine debris has evolved in time (ONCFS Martinique). Eight people haven't noticed any evolution and four people haven't answered the question. Because most observation networks and care centers have been created quite recently (table 6) and lack data, it is difficult to measure an evolution with the data currently available.

3. Analysis by region

3.1. Mainland France: Atlantic Ocean and English Channel coastlines

3.1.1. Observed impact

CESTM (Research and Care Center for Sea Turtles), based at the Aquarium of La Rochelle, has inventoried 656 cases of turtle strandings between 1988 and 2009, i.e. an average of 30 per year. Most observations involve leatherback and loggerhead turtles (figure 9). Intestinal or

gastric occlusions, and entanglement in pot ropes are the main causes of death linked with macro-debris in the region (figure 10).

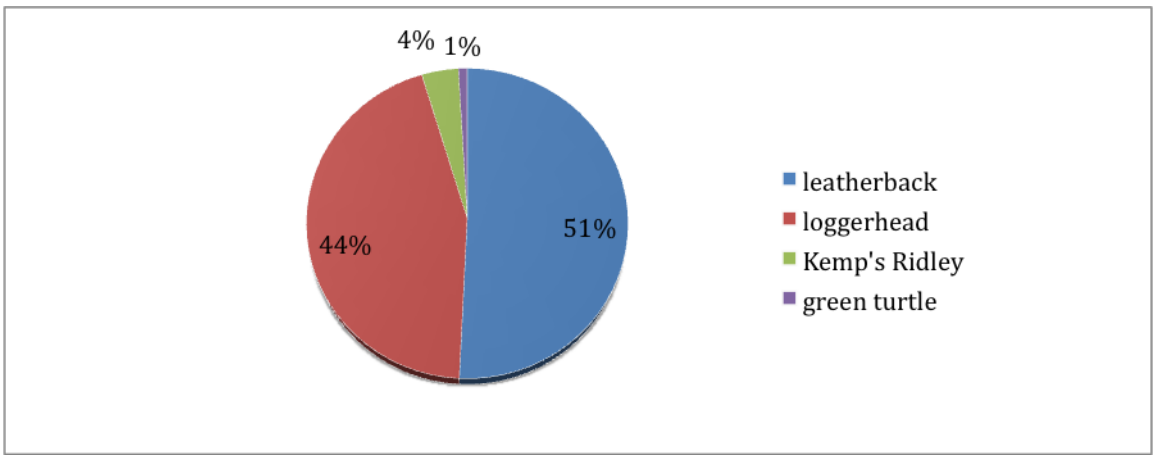

Figure 9. Species distribution of the 656 turtles stranded on the French Atlantic coastline between 1988 and 2009 (Source: La Rochelle Aquarium, CESTM).

Figure 10. Examples of the impacts macro-debris has on leatherback turtles that are stranded on the French Atlantic coast. a), b): occlusions linked with the ingestion of plastic bags. c), d): entanglement in ropes (Photographs: © La Rochelle Aquarium (CESTM)).

Out of 191 autopsied turtles, 30 percent had ingested waste (table 7), mainly plastic and fishing lines. To be more specific, 46 percent of the autopsied leatherback turtles and 16 percent of the loggerhead turtles had debris in their gastrointestinal tracts—the number of stranded and autopsied turtles was almost the same for both species (figure 11). Fishing gear marks were seen on 4 percent of stranded turtles, in this case only leatherbacks (figure 11).

Species	No. of stranded turtles	No. of necropsied turtles	No. of turtles with foreign bodies	No. of turtles with fishing gear marks	Ratio of No. with foreign bodies to No. Of autopsies (%)	Ratio of No. of fishing gear marks to No. of strandings (%)
Leatherback	333	95	44	29	46	9
Loggerhead	292	77	12	0	16	0
Kemp's ridley	25	15	1	0	7	0
Green turtle	6	4	1	0	25	0
Total	**656**	**191**	**58**	**29**	**30**	**4**

Table 7. Turtles collected on the French Atlantic coastline: inventory of strandings, debris ingestions and fishing gear marks (1988-2009, Source: La Rochelle Aquarium, CESTM)

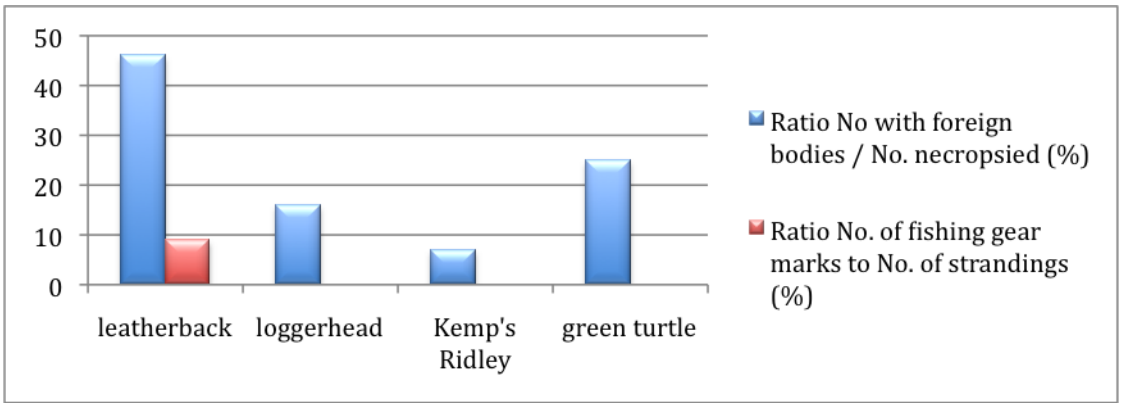

Figure 11. Percentage of marine turtles impacted by macro marine debris near the French Atlantic coastline, according to species (n = 656, data 1988-2009, Source: La Rochelle Aquarium, CESTM)

3.1.2. Actions put in place

Various actions are led to fight against the pollution of mainland France's coastline by macro-debris. For example, the *Mer-Terre* association, created in 2000, undertakes campaigns and creates educational awareness tools for decision-makers and the public. It also circulates quantitative and qualitative macro-debris monitoring protocols at the end of coastal cleanup sessions. Furthermore, its members build computing tools that can treat collected data, offer to carry out curative and preventive actions, and sensitize school children and the general public by means of conferences and educational documents.

3.2. Mainland France: Mediterranean coastline

3.2.1. Observed impact

About twenty turtles were observed every year between 2003 and 2010, most of which were loggerheads (figure 12). Out of 237 external observations, RTMMF noted 6 cases in which loggerhead turtles were impacted by macro-debris: 4 of them had evacuated or regurgitated debris such as plastic bags, strings and balloon fragments, and there were bits of nets around the other two's heads or necks.

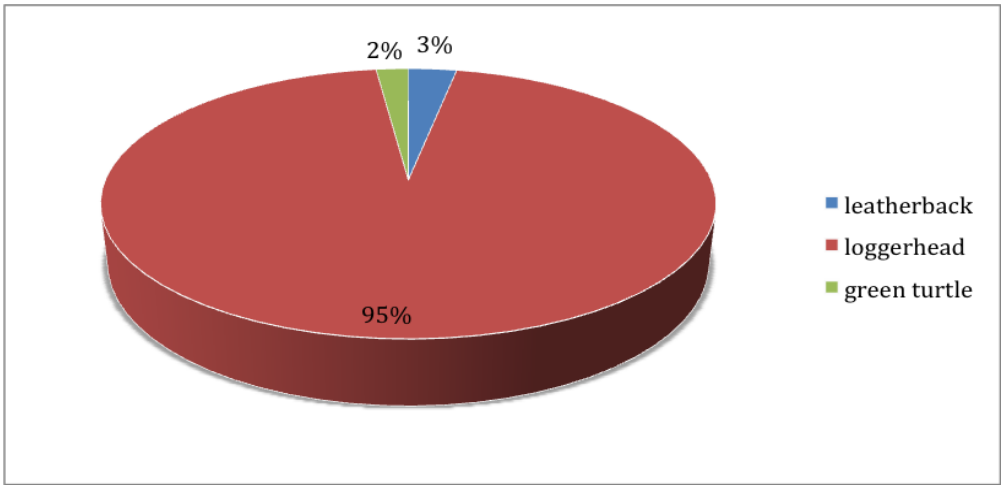

Figure 12. Species distribution of the turtles stranded on the French Mediterranean coastline between 2003 and 2010 (n = 237, Source: RTMMF). Only 3 or 4 Kemp's ridley turtles were observed during the whole period.

Since 2003, 146 turtles were collected and brought to CESTMed, of which 82 were alive and 64 were dead. All live turtles were released after being cared for and autopsies were performed on part of the dead turtles, according to their state of decomposition (appendix 3). In 2008, 20 autopsies revealed 7 cases of debris ingestion (figure 13). The ingested debris was mainly made of plastic, nylon string and hooks (figure 14).

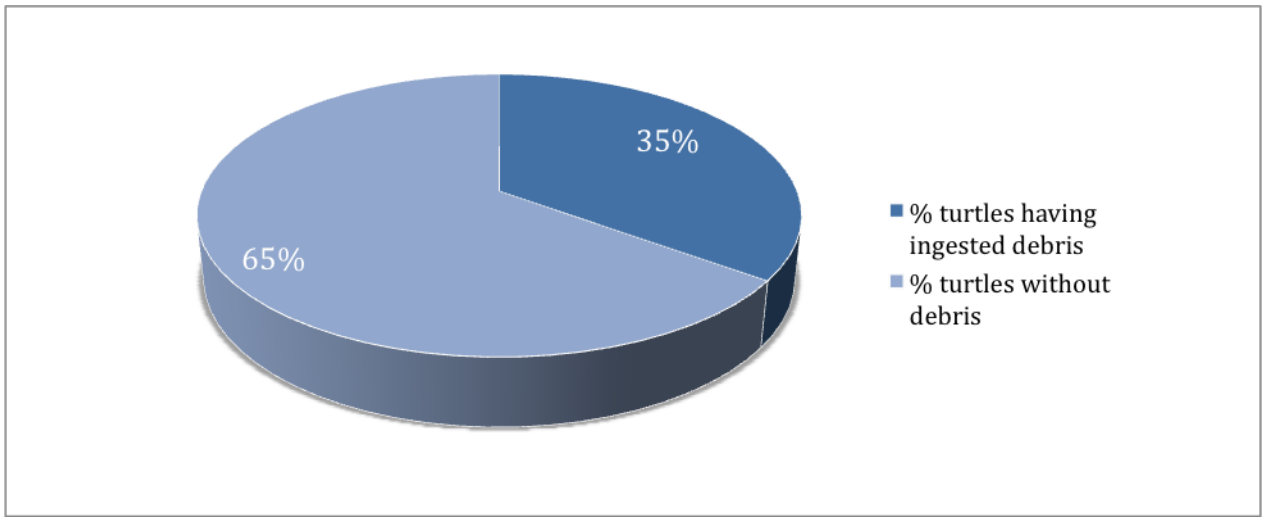

Figure 13. Percentage of green and loggerhead turtles autopsied in 2008 that had ingested debris (n = 20, source: CESTMed) .

Figure 14. Gastric contents of loggerhead turtles stranded on the French Mediterranean coastline showing the ingestion of debris (mainly plastic, three photographs) and a hook (X-ray) (Photographs ©CESTMed).

3.2.2. Actions put in place

RTMMF, CESTMed and several organizations for the protection of the Mediterranean coastal and marine environment (*Paul Ricard* Foundation, etc.) jointly endeavour to lead protection

and awareness actions against coastal pollution by macro-debris, e.g. "Clean island operation" and "Planet Sea" workshops at Embiez island.

3.3. French West Indies

3.3.1. Observed impact

From 2004 to the end of 2010, Guadeloupe's marine turtle observer network inventoried 660 turtle observations—dead or in difficulty, on land or at sea—of which 374 hawksbill turtles, 127 green turtles, 18 leatherback turtles, 1 olive ridley turtle and 131 turtles whose species was undefined (figure 15).

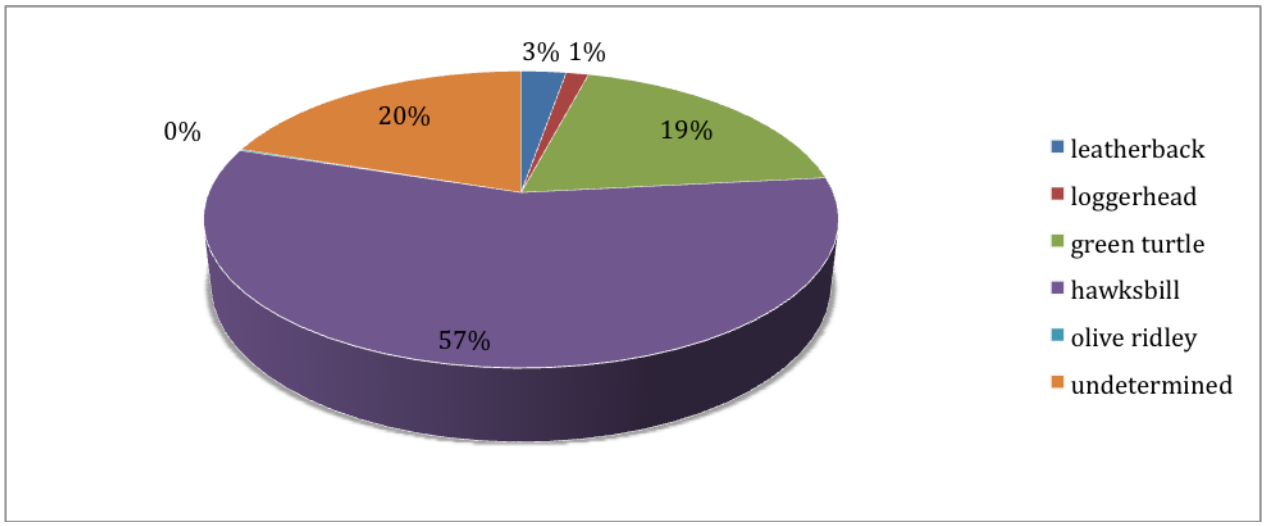

Figure 15. Species distribution of the 660 turtles observed in Guadeloupe between 2004 et 2010 (Source: ONCFS Guadeloupe).

Out of all the observed turtles, 84 percent were found dead and the cause of death or observed problems was determined in 407 out of 660 cases (figure 16). Based on data, the main threat to marine turtles in Guadeloupe is incidental by-catch in fishing nets, followed by animal disorientation.

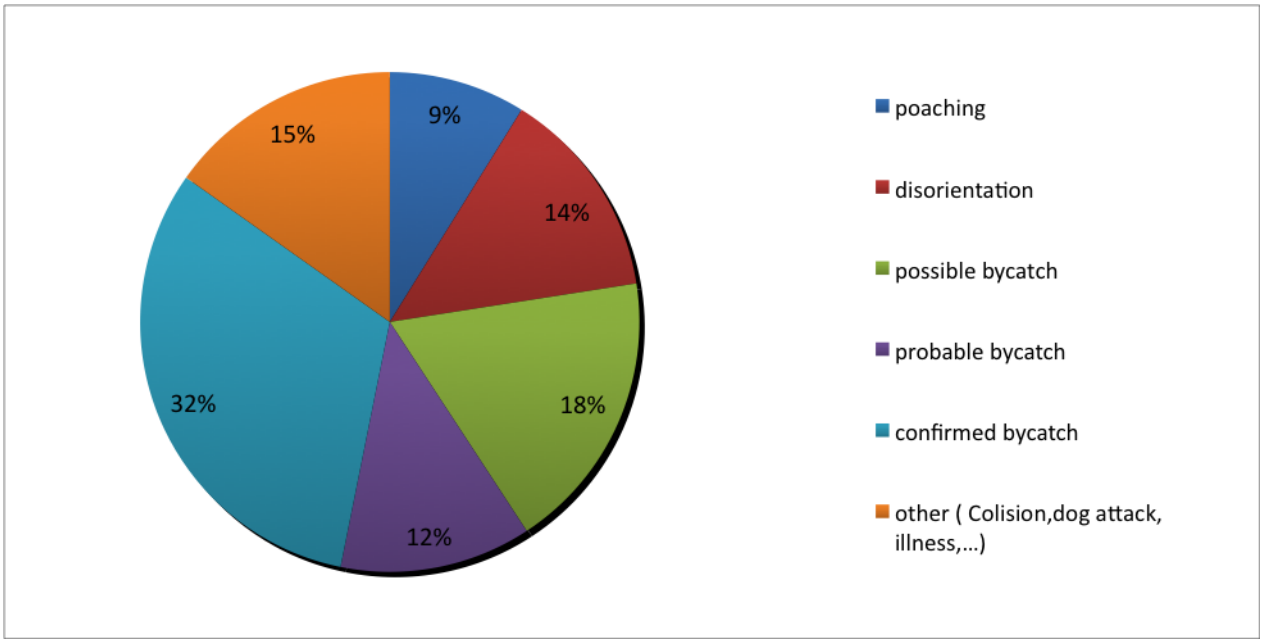

Figure 16. Causes of death or problems observed by Guadeloupe's marine turtle observer network between 2004 and 2010 (n = 407, Source: ONCFS Guadeloupe)

Between 2004 and 2010, 19 autopsies were performed, revealing 2 cases of macro-debris ingestion (10 percent): one case involved a piece of net and the other implicated bits of plastic and fishing lines that provoked a gastric occlusion and the animal's death. Out of all 660 observations, 6 cases were inventoried in which the turtles were impacted by macro-debris (table 8): 4 of them concerned macro-debris ingestion and in 2 cases, the turtles were entangled in abandoned nets.

Observation date	Status	Species	Necropsy	Cause of death	Macro-debris involved
Aug. 1, 2005	alive	Olive ridley	no	?	Excretion of a piece of plastic bag
May 17, 2007	dead	Green	no	?	Plastic bag in its mouth
Sept. 2, 2007	dead	Hawksbill	no	Asphyxia	Abandoned bottom trawl net
Mar. 22, 2008	dead	Green	yes	Occlusion	Pieces of plastic and lines
Apr. 21, 2008	dead	Hawksbill	no	Asphyxia	Abandoned net (20 m x 1.5 m)
Aug. 24, 2008	dead	Green	yes	?	Ingested piece of net

Table 8. List of observations made on turtles impacted by macro-debris in Guadeloupe (data 2004-2010, source: ONCFS Guadeloupe)

In general, live turtles in difficulty were taken to the aquarium in Gosier, where they were observed and taken care of by people from the Karet association. Unfortunately, we do not have any feedback on the data collected.
A network of observers also inventories marine turtle strandings on Martinique's coasts. According to ONCFS Martinique, the entanglement in abandoned ropes and fishing nets, and the ingestion of foreign bodies such as plastic debris and cigarette butts are the main problems noticed on animals that are impacted by macro-debris (observations made on green turtles). However, we were not able to access these data. Since 2006, five autopsies were performed; ONCFS Martinique plans to work with veterinarians to perform more of them (R. Le Scao 2011, pers. comm.).

3.3.2. Actions put in place

In the French West Indies, awareness actions have been put in place and beach cleanup programs are organized on a regular basis with local associations, diving clubs and, more generally, *FFESSM*, National Parks and *DEAL*.

3.4. French Guiana

3.4.1. Observed impact

In French Guiana, cases of strandings aren't systematically inventoried and dead turtles aren't autopsied. Therefore, we do not have precise quantitative data on the number of turtles that were found and impacted by macro marine debris. On average, members of the Kwata association observe a dozen leatherback turtles every year; they have noticed cases of wounds due to entanglement in fishing gear remains (figure 17a) and of marine debris ingestion (e.g. plastic).
Plot and Georges (2010) report the case of a leatherback turtle that dug its nest on a beach in French Guiana before expelling—with help from observers present on the beach—2.6 kg of plastic waste (mainly bags) that obstructed its cloaca (figure 17b, 17c). The turtle was then able to lay its eggs, seemingly fresh and undamaged, but accompanied by a white liquid and a little bit of blood, which could have been a sign of a possible lesion of the distal tract. According to witnesses, turtles that come and nest on the beaches of French Guiana can also be disturbed by

the presence of waste hindering their progression and making nest digging difficult (figure 18).

Figure 17. Examples of macro marine debris impacts observed on leatherback turtles in French Guiana. a) Dead turtle entangled in ropes. b), c) Turtle expelling plastic bags while laying its eggs (Photograph a: ©Kwata association; photographs b, c: ©*CNRS-DEPE*).

Figure 18. Examples of waste present on French Guiana's coastline that can hinder marine turtles' progression and nest digging (Photographs: ©Kwata association)

3.4.2. Actions put in place

Most of the waste present on French Guiana's coastline is believed to come from tourists who throw their trash directly onto the beach, and from coastal currents that run parallel to the coastline and transport waste from Brazil. The lack of beach amenities, such as garbage cans, can also exacerbate the problem. Several organizations try to fight against macro-debris by sensitizing the population to marine pollution and by organizing beach cleanups with help from municipalities, associations, the Region and federations of municipalities. For example, 1 800 kg of waste were picked up by the Amana Nature Reserve between October 2009 and

October 2010. The Nature Reserve, French Guiana *DREAL*, the Regional Council, the *Graine Guyane* association, and Awala-Yalimapo's city council support the project of the *Terre en Héritage* association: several storekeepers have decided to become actors for sustainable development and no longer give out disposable plastic bags since April 1st 2010.

3.5. Reunion island

3.5.1. Observed impact

Kélonia's care center has taken care of 53 turtles between 2005 and 2010, of which 28 loggerhead turtles, 12 green turtles, 8 olive ridley turtles and 5 hawksbill turtles (figure 19).

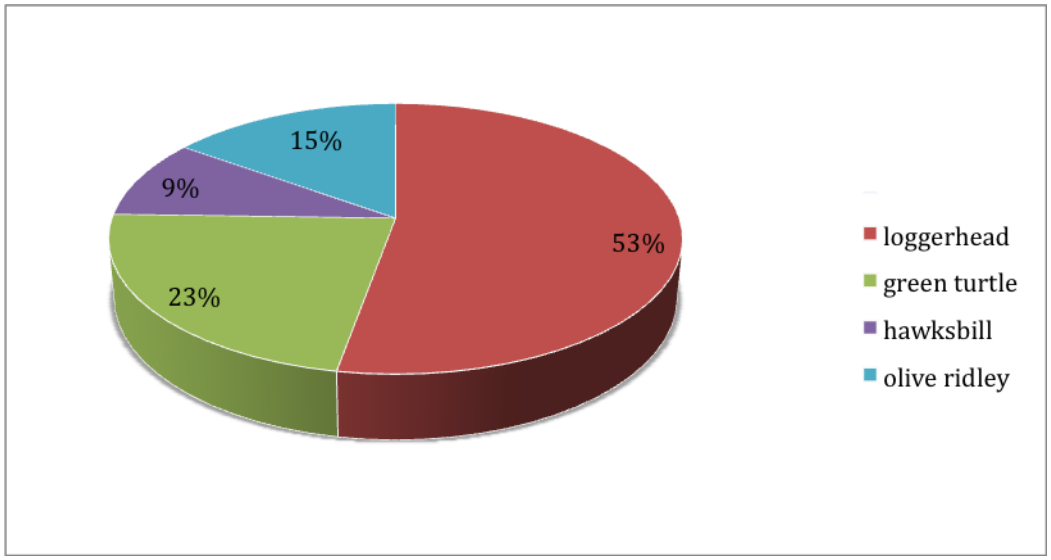

Figure 19. Species distribution of the 53 marine turtles collected by the care center in Reunion island between 2005 and 2010 (Source: Kélonia).

Live turtles and their feces were examined at the care center in order to know whether foreign bodies had been ingested; dead turtles were autopsied to determine the cause of death.
In total, 17 out of 53 observed turtles had ingested macro-debris (table 9). Green turtles and loggerhead turtles were the most concerned species (figure 20)—few observations have been made on the other species present around the island.

Species	No. of collected turtles	No. of turtles impacted by debris	Death directly liked to macro-debris
Green turtle	12	4 (33%)	2 (16%)
Loggerhead turtle	28	12 (43%)	0 (0%)
Olive ridley turtle	8	1 (12%)	0 (0%)
Hawksbill turtle	5	0 (0%)	0 (0%)
Total	**53**	**17 (32%)**	**2 (4%)**

Table 9. Overview of the turtles impacted by macro-debris in Reunion island between 2005 and 2010 (No. = number).

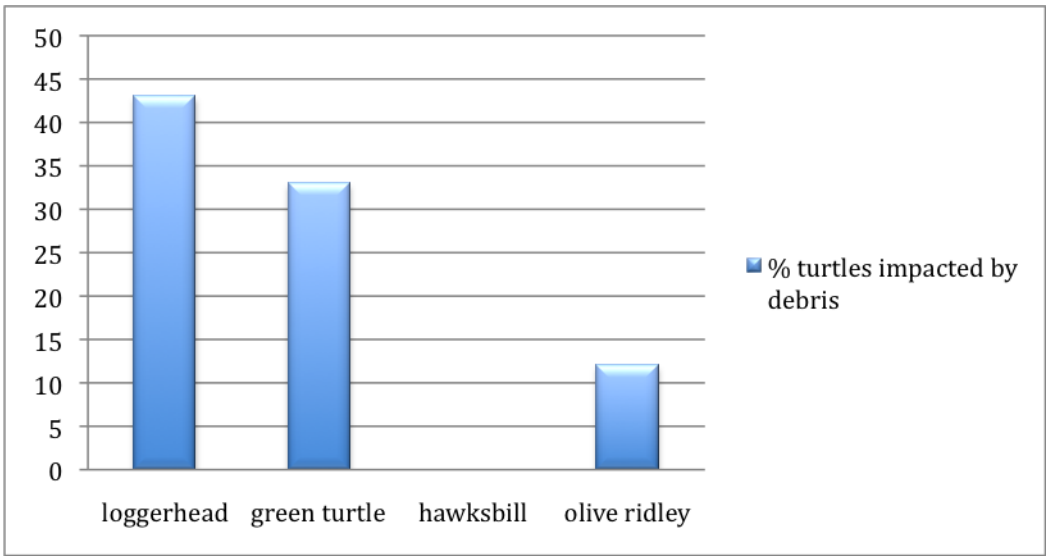

Figure 20. Percentage of sea turtles impacted by marine debris close to Reunion island, according to species (n=53, data 2005-2010, Source : Kélonia)

Most of the debris found in the animals' gastrointestinal tracts are fragments of plastic (figure 21). Two green turtles died of an intestinal occlusion due to the ingestion of plastic. Few wounds due to entanglements in lost, abandoned or discarded gear were noted. The entanglement of a live immature green turtle at sea—freed by its observers—was reported at the issue of a field mission.

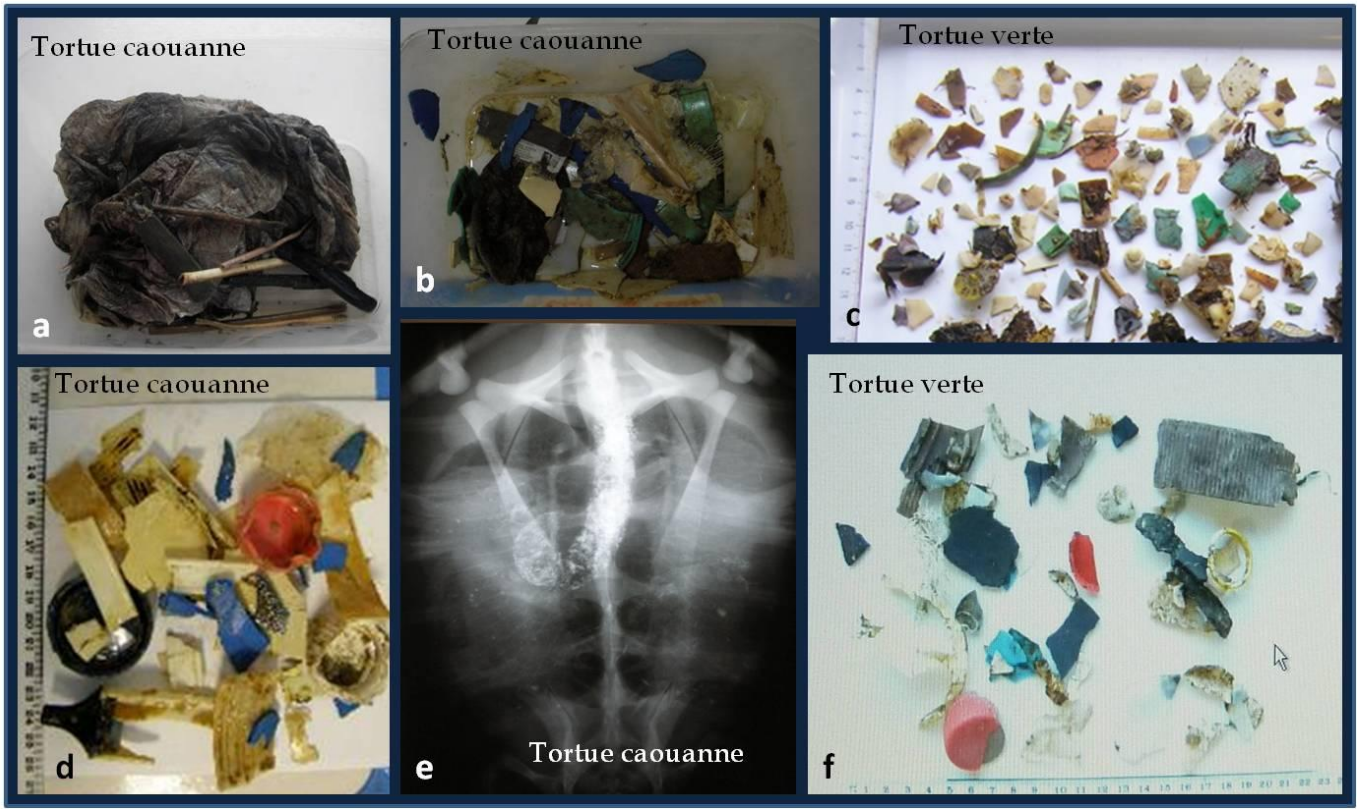

Figure 21. Debris ingested by loggerhead and green turtles in Reunion island. (a) (b) Debris found in feces, (c) (d) (f) Debris found in gastric contents, (e) X-ray showing the presence of debris in a loggerhead turtle's gastrointestinal tract. (Photographs ©Kélonia). *Tortue caouanne= loggerhead C. caretta., Tortue verte= green Chelonia mydas.*

3.5.2. Actions put in place

To fight against macro-debris in Reunion island, local associations (Kélonia, Globice, Surfrider foundation) and the Marine Nature Reserve work to sensitize the population to the problem. Furthermore, beach cleanups are organized on a regular basis by local governments (municipalities, federations of municipalities). Disposable plastic bags have been compulsorily removed from all superstores and some stores have removed them willfully.

3.6. Mayotte

3.6.1. Observed impact

Mayotte's Marine Turtle Observatory (OTM) has inventoried ten to twenty marine turtle strandings per year since 2008 (appendix 4), mainly green and hawksbill turtles. Between 2008 and 2010, an average of eleven dead stranded turtles whose causes of death are unknown

were found per year; this may be explained by the fact very few were autopsied. Out of eight turtles that have been autopsied since 2004, two of them (hawksbill turtles) had ingested marine-debris that a priori caused their death (figure 22). One of them had swallowed a piece of net (7 x 13 cm) and the other had eaten a 2 cm flat fragment of plastic that provoked an obstruction and a perforation before causing a peritonitis.

OTM agents have observed a turtle stop digging its nest on a beach in Mayotte because it was hindered by a plastic bag buried in the sand. This resulted in the turtle returning to the sea without laying its eggs. In another case, juveniles were seen having difficulties emerging from their nest because they were entangled in buried ropes.

Figure 22. Impact of macro marine debris on two hawksbill turtles in Mayotte.
Left: intestinal occlusion of a hawksbill turtle that had ingested a piece of net. Right: fragment of flat plastic that caused an obstruction and a peritonitis and led to death (Photographs: ©Mireille Quillard).

3.6.2. Actions put in place

Various village associations organize coastal cleanups with help from administrative organizations (*DEAL*, Site Management Bureau, Environmental Education Service of the Direction for the Environment and Sustainable Development/*Conseil Général* of Mayotte, Marine Park of Mayotte, Syndicate of Municipalities, etc.). These cleanups take place at least once a year, before the wet season, in October or November. Mayotte currently has no structures to manage waste efficiently, especially when it comes to collecting, sorting and recycling. This results in waste piling up in four open-air landfills (M. Quillard, pers. comm.). *ADEME* has financed a study prior to the progressive establishment of waste recycling

industries. Moreover, it is forbidden since January 1st, 2006 by prefectoral decree to sell or give out plastic bags in supermarkets. Furthermore, a Departmental Plan for the Elimination of Household Waste and Other Comparable Waste (*PEDMA*) started in 2010 for a 10 year duration. It is correlated to the Water Development and Management Plan (*SDAGE*) and the Land Settlement and Sustainable Development Plan (*PADD*).

3.7. Scattered Islands

3.7.1. Observed impact

No data were transmitted on the impact macro-debris has on marine turtles in the Scattered Islands of the Indian Ocean (Europa island, Bassas da India atoll, Juan de Nova island, Glorioso islands, and Tromelin island). Marine turtles regularly get caught in drifting FADs (J. Bourjea, F. Poisson and P. Chavance 2009, pers. comm. *in* Claro et al 2010). According to the observer program led in 2009 (465 days of observation) on foreign purse seiners in Mayotte and the Scattered Islands' EEZs, three hawksbill turtles and seven green turtles were captured by nets constituent of drifting FADs (Clot 2009 *in* Claro et al 2010).

3.7.2. Actions put in place

The administration of the French Southern and Antarctic Lands (*TAAF*) that manages the Scattered Islands of the Indian Ocean has included several obligations related to waste management on fishing vessels that ask for a license into the decree n° 2008-154 of 17 December 2008 (prescribing rules for fishing activities in territorial waters): "… it is strictly forbidden to throw away plastic waste such as synthetic ropes, nets, bags and other similar objects; waste that cannot be thrown away must be kept on board and unloaded on land ...".

3.8. New Caledonia

3.8.1. Observed impact

Every year, the people from the *Aquarium des lagons* in charge of the "Initiative for Marine turtles in New Caledonia" program collect marine turtles (mainly green turtles) brought to them by private individuals. Out of ten turtles sheltered at the Aquarium since 2009, only one

was apparently impacted by macro marine debris; the animal's autopsy revealed an intestinal occlusion (figure 23). However, dead animals aren't systematically autopsied, which makes it difficult to know to what extent turtles ingest macro-debris in New Caledonia. The Aquarium's manager believes that occlusions are frequent and that 90% of collected turtles suffer from pathologies linked with macro-debris. We do not have any further information about the nature of these pathologies.

Furthermore, according to the Association for the Protection of New Caledonian Nature (*ASNNC*) macro-debris allegedly isn't an important threat compared to other problems such as the consumption of turtle meat.

Figure 23. Necropsy of a green turtle revealing an intestinal occlusion that provoked the animal's death (*Aquarium des Lagons*©).

3.8.2. Actions put in place

Several protection and sensitization actions linked with macro-debris have already been put in place in New Caledonia. For example, Quick fast food restaurants no longer give out balloons (that burst in altitude and fall down in the ocean or on land) and plastic bags are no longer given in supermarkets. Certain beaches of New Caledonia are cleaned up by the Surfrider Foundation and the *Bwara tortues marines* association. Since 1992, *ASNNC* yearly carries out a

campaign called "Clean New Caledonia Operation" (www.cleanuptheworld.org). It takes place from August to the end of October on the entire territory and is aimed to make thousands of teenagers pick up all the debris they find on land, on beaches, on small islands and at sea. The *Aquarium des lagons* takes part in municipal and ocean celebrations to sensitize the local population to the problems of ocean pollution by macro marine debris. In the field of waste and the environment, a framework agreement aimed to promote a modern waste management system was renewed by *ADEME* in 2008 with each province of New Caledonia for a 3 year period.

3.9. French Polynesia

3.9.1. Observed impact

Between 2004 and 2010, the *Te Mana o Temoana* marine turtle care center has observed around 80 marine turtles (i.e. a dozen per year) and autopsied all of the dead animals when their state of decomposition allowed it. Green and hawksbill turtles are the most observed species and 12% of them have known difficulties linked with macro marine debris. The macro-debris involved are mainly plastic waste that cause intestinal occlusions and death.

The *Te Honu Tea* association, which studies and works for the preservation of Polynesia's marine turtles, also reported two observations implying fishing net remains and ropes in which turtles were stuck. The association doesn't perform autopsies, meaning no data are available concerning macro-debris the marine turtles might have ingested.

3.9.2. Actions put in place

The *Te Mana o Temoana* and *Te Honu Tea* associations support local associations that fight against ocean pollution by waste, i.e. the *Action Nature* association, whose mission is to inform, sensitize and educate the population to the respect and protection of the environment. The association thus leads waste cleanup operations on the field and has put in place a program called "Stop Pollution" that asks the population to report illegal dumps, dirty rivers, beach dumps and chemical pollution in Polynesia.

4. Summary and general conclusion

Our study shows that all marine turtle species observed on the national territory are impacted by macro marine debris.
Autopsies (and observations of turtles being cared for in Reunion island) reveal that the proportion of turtles that have ingested macro-debris, all species included, varies from 10 to 35 percent according to different regions of the national territory (figure 24).

Despite the biases due to a limited amount of data and the fact that the observations are made on turtles in difficulty, these figures suggest that macro marine debris represents a significant cause of mortality for these threatened species.
It is difficult to measure the impact of macro-debris on marine turtle populations precisely. The data indeed concern only stranded turtles or turtles collected at sea at a given time, and that have been examined and/or autopsied; they do not show the cases of turtles impacted by macro-debris that have died at sea, or those that didn't show any signs of impact at the time they were observed but might have been impacted previously.

Furthermore, the number of observations per species is too variable to be able to say one species is more likely than others to ingest macro-debris (table 10).

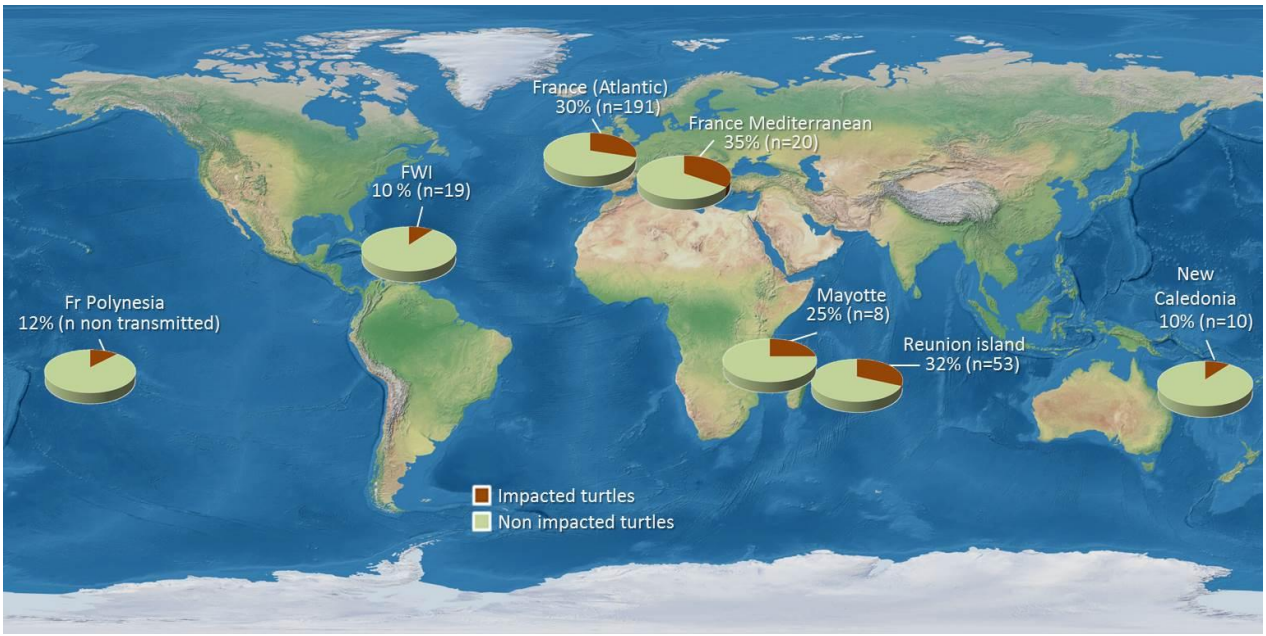

Figure 24. Proportion of turtles impacted by macro marine debris compared to the total number of turtles observed in different French regions (data from necropsies and from observations made by the care center in Reunion island).

It was possible to calculate the percentage of turtles that had ingested macro-debris for three species (leatherback, loggerhead and green turtles)—data were insufficient for the other species. Figures show that nearly one leatherback and one loggerhead turtle out of two had ingested macro marine debris.

Species	Percentage of turtles that had ingested macro-debris	Average	Source
Leatherback turtle	55%[1], 46%[2]	48% (n=170)	[1]Duguy et al. 2000, [2]données CESTM
Loggerhead turtle	79%[3], 16%[2], 35%[4], 43[5]%	43% (n=179)	[3]Tomas et al. 2000, [2]données CESTM, [4]CESTMed, [5]Kelonia
Green turtle	25%[2], 33%[5]	29% (n=16)	[2]CESTM, [5]Kelonia
Hawksbill turtle	Insufficient data		
Kemp's ridley turtle			
Olive ridley turtle			

Table 10. Percentage of marine turtles that were found in mainland France and its overseas territories and had ingested macro-debris.

Based on the overview of the survey's participants' opinion, the type of waste that is most frequently found in marine turtles' gastrointestinal tracts is plastic debris, especially plastic bags and pieces of wrappers, followed by small fishing gear such as hooks, thin nylon string or pieces of nets. This observation is consistent with the worldwide and European trends (Brown & Macfayden 2007, Wabnitz & Nichols 2010).

Based on the information from the survey, mortality directly linked with the ingestion of macro-debris rises to about 3.5% (7 cases of occlusions or serious lesions out of about 200 autopsies). Several examples show that turtles manage to regurgitate or evacuate waste in their feces. For most participants, macro marine debris currently isn't the main threat to marine turtles present in French territories. The main causes of mortality are believed to be incidental by-catch in fishing nets, poaching, and predation or wounds caused by dogs.

In 1.4% of the cases, participants in the survey mentionned proven cases of entanglement in lost, abandoned or discarded fishing gear (14 cases mentionned out of over 1 000 external observations). The Kwata association has a few extra non-quantified observations. However, the impact of this type of macro marine debris is probably underestimated because it is hard to distinguish cases of entanglements in abandoned fishing gear from incidental by-catch during fishing operations (J. Sacchi, pers. comm.). Furthermore, turtles caught in this gear that haven't been stranded and found cannot be accounted for. Anderson et al. (2009) reveal that in the Indian Ocean, near the Maldive islands, 55 percent of the olive ridley turtles observed at sea were found entangled in abandoned fishing gear (n = 45, observations made between 1999 and 2009). The authors make proposals to avoid marine turtles from getting entangled in abandoned fish aggregating devices (FADs). The nets that are attached under these devices make rafts that are indeed responsible for capturing numerous marine turtles (and other endangered species) that approach them. The European research "MADE" program (http://www.made-project.eu/), whose goal is to propose mitigation measures to the negative impacts pelagic fisheries have, contains a section dedicated to the conception and experimentation of FADs made of biodegradable materials (http://www.ioseaturtles.org/pom_detail.php?id = 106).

To conclude, it isn't possible to precisely measure the impact of macro-debris on the marine turtle populations of mainland France and its overseas territories because of the small amount of data, but these data describe impacts on an individual scale. Adult marine turtles can die from ingesting debris or being entangled in abandoned fishing gear. Lescure (2001) stresses that for endangered species, the death of reproductive adult animals can have a dramatic impact on the dynamic and survival of the populations. The problem of macro marine debris is thus an essential element that must be taken into account for the conservation of marine turtle populations. It has been observed worldwide that the quantity of macro marine debris and its impacts on the ecosystems are increasing; this worries environmental stakeholders in France and abroad (*Robin des Bois* association 2009, Hofer 2008) and marine turtle specialists (Wabnitz & Nichols 2010).

Developing post mortem examinations and observations in care centers would increase the amount of data and help to evaluate more precisely the impact macro-debris has on marine turtles. The current level of data collection on the national territory varies according to the different local governments—it is mainly based on volunteer organizations with limited means and depends on the existence of care centers, alert networks in case of strandings and/or incident by-catches, and the local situation (poaching, size of the territory, organization motivation, etc.). However, developing this observation activity will hardly be sufficient to collect all of the data that is necessary to measure a precise impact on marine turtle populations, considering they spend most of their biological life cycle at sea. Considering the alarming global situation, it is interesting only if it helps measure the efficiency of measures that are taken.

Recommendations for action

As exposed in paragraph 1.3., several publications, reports and articles analyze the situation on a worldwide scale and propose actions (table 11). Different resolutions of the United Nations General Assembly currently mandate and compel to put actions in place to reduce macro marine debris. A report written by FAO and UNEP in 2010 also proposed guidelines to limit the quantity of lost, abandoned or discarded fishing gear (Macfadyen et al. 2010). In France, all of the "recommendations for action for a coordinated plan for reducing floating or stranded macro-debris in rivers, harbors, coasts and at sea" have been approved—they are

now being prioritized and the research of a "macro-debris fund" is underway in order to put the actions in place.

Certain recommendations for action specifically concern marine turtles (table 11) and because these species are more abundant in France's overseas territories, it is particularly important to put them in place there. The first evaluation that was led in the framework of the Strategy for the Marine Environment Framework Agreement only concerns mainland France's coastlines and seas. This overview will complete the information that can be found in the first evaluation and will be able to serve as a base for i) evaluating the measures that have already been put in place on the French territory, and ii) defining measures to put in place or reinforce to reduce the impact of macro marine debris on marine turtles.

Types of measures	**General "macro-debris" actions**	**Specific "marine turtle" actions**
Reinforce the legislation and the control of its enforcement	► Clarify the legal status of macro-debris and of the pollution it induces	► Constrain the identification and marking of fishing gear
Develop infrastructures for waste collection	► Forbid all kinds of discards at sea	► Constrain the report of lost, abandoned or discarded fishing gear
	►Enforce strict sanctions when waste is illegally discarded (fines)	**►Forbid beach fires**
	►Put in place a tax system, e.g. the Polluter Pays Principle	►Forbid balloon releases during events
	► Strengthen the enforcement of regulations concerning waste dispersal from landfills by the wind	
	►Integrate macro-debris in the priority stakes of international conventions	
	►Develop technical infrastructures to collect, sort and recycle waste	**►Install garbage cans on beaches to limit discarded waste on the coast**
Empower and sensitize	►Improve signaling of and accessibility to waste collection infrastructures	►Install awareness and warning signs on beaches
	►Empower waste producers and wrapper designers	►Lead information campaigns to explain the damage inflicted upon marine turtles to fishermen

Clean the ocean and the coast	►Improve water treatment and management	►Encourage fishing gear makers to use more biodegradable materials
	► Sensitize the population to ways of being less wasteful	► Encourage boat users to declare large lost, abandoned or discarded fishing gear
	►Make national multimedia campaigns during peak-time audience	**►Make presentations in schools about the problems marine turtles face because of macro marine debris**
	►Educate and sensitize school children	
	►Check for the presence and enforcement of waste management plans on boats	
	►Generalize actions to make people willfully bring back to land any waste collected in fishing gear	►Detect lost, abandoned or discarded fishing gear with the help of sonars
Put structures and studies in place	►Organize waste trawling/dredging programs in heavily polluted areas	►Bring back to land all lost, abandoned or discarded fishing gear when they are localized
	► Organize coastal cleanups on a regular basis, especially after cyclones and storms	**►Process observation data and write reports**
	►Study the origin, transformation and behavior of debris in the ocean and the food chain	**►Create/Structure care centers to care for turtles, check their feces and perform autopsies**
	►Study the sanitary and ecological impact of waste decomposition	**► Create/Structure observation networks**
	►Process data from coastal waste observations	**►Standardize data collection in different regions of mainland France and its overseas territories**

Table 11. Main preventive and curative recommendations for action to reduce the quantity of macro marine debris and its impact on marine turtles, based on literature (Topping 2000, Brown et al. 2005, Matsuoka 2005, *Robin des Bois* association 2009, UNEP 2005, 2009b, Macfadyen et al. 2010), the answers to the survey, and the conclusions of this report (in bold).

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Appendices

Appendix 1. Questionnaire sent to GTMF members

SURVEY

GROUPE TORTUES MARINES FRANCE

GTMF

Sea turtles and marine debris in France

Author of the form:

Organization name:

Filled in on:

Address:

Phone No.:

Skype address:

Name and contact details of the veterinarian in charge of examining turtles:

If your organization isn't in a care center, please indicate which care center turtles are sent to:

OBSERVATIONS

Have you ever observed turtles with problems linked with macro-debris?

☐ YES ☐ NO

Do you fill in descriptive forms (computer or paper file) of your observations (strandings, incidental by-catch, observations at sea, autopsies)?

☐ YES ☐ NO

If so, is it possible to access these files?

☐ YES ☐ NO

Do you write reports or overviews of these observations on a regular basis?

☐ YES ☐ NO

If so, is it possible to access these files?

☐ YES ☐ NO

Do you have photographs illustrating the problems caused by macro marine debris for marine turtles?

☐ YES ☐ NO

If so, is it possible to have these photographs to illustrate our report?

☐ YES ☐ NO

If you do not own any forms or reports that may be transmitted to us, please answer the following questions insofar as possible:

On average, how many turtles that are impacted by macro-debris do you collect in your center every year?

What is the percentage of these observations compared to the total number of observations?

If you don't have any quantitative data, what do you think the percentage might be?

Do some types of macro-debris cause more problems for marine turtles than others?

☐ YES ☐ NO

If so, which ones?

In your center, which are the most recurrent and serious problems linked with macro-debris?

Have you noticed an evolution in time of the number of marine turtles that are victims of macro-debris?

☐ YES ☐ NO

If so, how is this situation evolving?

Are some marine turtle species more impacted by macro marine debris than others?

☐ YES ☐ NO

If so, which ones?

FIGHT MEASURES

In your region:
Have you identified sites where debris is more abundant?

☐YES ☐ NO

If so, what are the names of these sites?

Is the presence of macro-debris at sea monitored in or near turtle habitats?

☐ YES ☐ NO

Are actions taken and efforts made to limit the problems caused by macro marine debris (beach cleanups, awareness campaigns, etc.)?

☐ YES ☐ NO

If so, which ones? By and with who?

Do you have proposals for action that can be put in place to limit the negative impact of macro marine debris on turtles?

Appendix 2. Names and contact details of the people and organizations that have participated to the survey.

Participant	Organization name	localization	Address	Email	Phone number
Jean-Yves Georges et Virginie Plot	CNRS IPHC-DEPE	Guyane	23 rue Becquerel, BP28 67037 Strasbourg cedex 2	jean-yves.georges@c-strasbourg.fr	03 88 10 69 47
Cécile Gaspar	Te mana o te moana	Polynésie Française	BP 1374 Papetoai Moorea 98729 Polynésie Française	cecile.gaspar@gmail.com	0689 56 40 11
Eric Delcroix	ONCFS	Guadeloupe	Chemin de Boyer, Boisbert, 97129 Lamentin Guadeloupe	eric.delcroix@developpement-durable.gouv.fr	0690 54 28 11
J.B. Senegas et Amélie Laencia	CESTMed	Méditerranée	Avenue du Palais de la Mer, BP106, 30240 Le Grau-du-Roi	contact@cestmed.org	04 66 51 57 57
Guy Oliver	RTMMF	Méditerranée	Parc National de Port-Cros, Castel Sainte Claire 83400 Hyères	guy.oliver@free.fr	04 68 50 83 27
Guillaume Feuillet	KWATA	Guyane	BP 672, 97335 Cayenne Cedex	guillaume@kwata.net	05 94 25 43 31
Jean Louis d'Auzon	ASNNC	Nouvelle-Calédonie	12 Bd Vauban, BP 1772, 98845 Nouméa Cedex	asnnc@canl.nc	0687 28 32 75
Rozenn Le Scao	ONCFS	Martinique	4 Bd de Verdun, 97200 Fort de France	rozenn.le-scao@developpement-durable.gouv.fr	0696 23 42 35
Stéphane Ciccione	Kélonia	La Réunion	46 rue du G. De Gaulle 97436 Saint Leu	stephaneciccione@kelonia.org	0262 34 81 10
Pierre Morinière et Florence Dell'Amico	CESTM	France Atlantique	Aquarium La Rochelle, Quai Louis Prunier BP 4 17002 La Rochelle Cedex 01	contact@aquarium-larochelle.com	05 46 34 00 00
Natacha Agudo et Richard Farman	ITMNC	Nouvelle-Calédonie	Aquarium des Lagons, BP 8185 98 807 Nouméa – Nouvelle-Calédonie	richard.farman@aquarium.nc	0687 26 27 31
Mireille Quillard	OTM	Mayotte	BP 101, 97600 Mamoudzou	mireille.quillard@cg976.fr, mireille.quillard@wanadoo.fr	0269 64 98 59
Sophie Gaugne	Te honu tea	Polynésie Française	BP 8980 Taravao, Tahiti	tehonutea@mail.pf	0689 52 14 05

Appendix 3. Example of an necropsy report indicating the ingestion of plastic debris by a loggerhead turtle (provided by CESTMed)

LE GARD
CONSEIL GÉNÉRAL

Laboratoire départemental d'analyses

Rapport d'essais

DOSSIER : 10050600248601
DATE D'EDITION : 18/05/2010

Copie à :
LDA 30

Destinataire du rapport
CEST MED(Centre études Sauvegarde Tortues Marine
Avenue du Palais de la Mer
30240 LE GRAU-DU-ROI

Propriétaire de l'échantillon
Nom : CEST MED(Centre études Sauvegarde Tortues M
Commune : LE GRAU-DU-ROI
N° Cheptel

RAPPORT D'ANALYSE

DATE DE PRELEVEMENT :	DATE DE RECEPTION : 06/05/2010	DATE D'ANALYSE : 06/05/2010

Nature du prélèvement Cadavre **Mode d'acheminement** POSTE

Espèce : Tortue CAOUANNE ***Age :*** adulte
Analyses demandées : Autopsie animaux marin >5kg
Remarques : Néant
Commentaires :

Paramètres	Résultats	
Coproscopie parasitaire quantitative		
Numération en cellule de Mac master	Résultat :	Absence de formes parasitaires
Autospie animal marin		
Aspect général	Résultat :	Dimensions (cm) : L courbe standard=60.5, courbe LDS=63, largeur=57, plastron (longueur)=47.5, machoire=12.3, Poids : 29.5 kg; Conservation : Moyenne. Congestion généralisée suite à congélation; Etat général : Normal; Cavité thoracique/abdominale : normal
Système nerveux	Résultat :	Encéphale : Putréfaction avancée
Appareil respiratoire	Résultat :	Trachée : Normale; Poumons : Congestionnés. Absence d'eau.
Appareil circulatoire	Résultat :	Coeur : Congestionné
Appareil urogénital	Résultat :	Reins : Congestionnés
Appareil digestif	Résultat :	Aspect général : Normal; Contenu : Normal. Présence de nombreux corps étrangers (plastiques....) dans l'estomac mais pas d'occlusion observée.
Glandes Annexes	Résultat :	Foie : Congestionné
Prélèvements	Résultat :	Foie; Encéphale
Identité de l'échantillon : *Encéphale*		
Bactériologie classique		
Mise en culture	Résultat :	Shewanella putrefaciens en culture pure après enrichissement
Identité de l'échantillon : *Foie*		
Mise en culture	Résultat :	Examen bactériologique sans signification spécifique

Conclusion : L'examen nécropsique et les analyses complémentaires ne permettent pas de conclure sur l'origine de la mort de l'animal.

Appendix 4. Example of a stranding form (provided by Mayotte's Marine Turtle Observatory)

FICHE "Echouage" TORTUE MARINE Mayotte N° Fiche : …….

A) Date d'observation:……/……/…… par Nom (membre réseau) : ……

Nom 1er observateur : …… et Tél. : …… Date découverte : ……

Commune (et village à proximité) :…… GPS …..° …..' …."

Plage (nom et numéro OTM) ou lieu dit : :……

☐ trouvé en mer ☐ échoué ☐ arrière plage ☐ autres

Rmrq (code A verso fiche) : ……

B) IDENTIFICATION

Espèce : ☐ Verte (Cm) ☐ Imbriquée (Ei) ☐ Caouane (Cc) ☐ Luth (Dc) ☐ Olivâtre (Lo) ☐ indéterminée ☐ autre :……

Sexe : ☐ Femelle ☐ Mâle ☐ Immature ☐ Indéterminé

N° bague Gauche : ……N° bague Droite : …… N° Puce : ……

Poids : Pesée : ….. kg Estimé : …… kg

Statut : ☐ Vivante viable ☐ Vivante non viable ☐ vivante ? (viabilité indéterminé) ☐ mort

Cause découverte : ☐ pêche ☐ braconnage ☐ chiens ☐ collision ☐ naturelle ☐ autre : ……

Indices de l'origine de la mort ou de la blessure (code B verso fiche) : ……

……

C) ANIMAL VIVANT ☐ Relâché sur place ☐Capturé pour mise en soin

Mise en soin Date :……/……/…… Mise en liberté Date :……/……/……

Lieu :…… Lieu :……..

Poids :……kg Poids :……kg

Observation, soins : ……

……

D) ANIMAL MORT (voir au dos pour précision état fraîcheur, lieu et causes mortalité)

Etat de fraîcheur : ☐ frais ☐ putréfié (odeur de putréfaction, asticots, gonflement) ☐ sec ☐ indéterminé

Critères de détermination (code D verso fiche) : ……..

Date de la mort : ☐ 1 jour ☐ 1 semaine ☐ > à 1 semaine ☐ date précise : ……/……/……

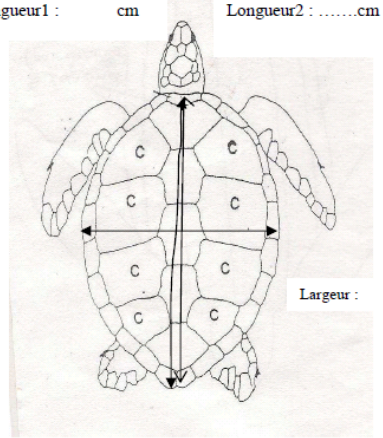
Rapport d'autopsie complété : ☐ oui ☐ non 976_initiale_date(J-M-A)_esp_sexe_N°nbIndiv

Prélèvements faits : ☐ Code1 ☐ Code2 ☐ Code3 Référence : 976_

Devenir cadavre : ☐ coulé en mer ☐ Enterré sur place ☐ transfert congélateur ☐ Détruite

☐ Autre : …… Rmrq : ……

ongueur1 : cm Longueur2 : …….cm



Largeur : cm

E) Cocher et localiser sur le schéma les marques ou blessures éventuelles

Remarques : (préciser si blessures cicatrisées ou fraîches -facteurs de la mort-)

F) Photos prises ☐ nb & coordonnées

……

Autres observations

:……

……

FICHE A RETOURNER A : Observatoire Tortues Marines de Mayotte SPN/DEDD/Conseil Général

Tél. : 0269 64 98 59 - 0639 21 16 83 ou 67 24 62 Fax : 0269 64 98 98 – mireille.quillard@cg976.fr

Eléments complémentaires :

- Date réception de l'information (réservée OTM) :

- Code A : Lieux de dépôt de l'animal :
  ☐ caché dans végétation ☐ bas de plage
  ☐ découvert sur plage ☐ enfouie ou enterrée dans le sable
  ☐ sur rocher ☐ dans mangrove
  ☐ flottante dans l'eau : ☐platier ☐lagon ☐hors barrière
  ☐ autre, préciser :

- Si femelle : trace de sa montée ? ☐ oui ☐ non

- Code B : Exemple d'indice des causes de blessure ou mort : pêche : présence d'un morceau de filet ou d'un crin ou d'un hameçon ; braconnage : trou de harpon, présence de carapace ou plastron ou tête ou 2 pattes ou présence d'un cordage, retrouvée sur dos sans obstacle ; prédateur : morsure : à l'épaule = chien, tout ou partie de patte absente, sur carapace : empreinte mâchoire de requin) ; collision : Coupure liée à une hélice bateau ; carapace défoncée (choc avec engin) ;Naturelle : coincée sur des rochers ou par des racines sur plage ou dans mangrove ou sur platier (+ soleil), enfouissement sous éboulement (montée et pas de descente + éboulement), épuisement ? ; présence d'hydrocarbure ; présence d'un déchet (Code 2) : morceau de tissu, filet, plastique.

- Code D : Critère de détermination fraîcheur ou putréfaction

- Odeur : ☐ très forte ☐ début ou peu ☐ pas d'odeur de putréfaction
- Taille asticot : ☐ 2 mm ☐ >1cm ☐ pas d'asticot
- Couleur sang : ☐ rouge ☐ noire ☐ séchée
- Présence et couleur chair :
- Décollage des écailles : ☐aucune ou 1 ou 2 ☐toutes ou beaucoup

Abstract

With the dramatic increase of the quantity of waste in the ocean, it becomes more and more frequent to observe marine turtles impacted by macro-debris (turtles entangled in pot ropes and fishing lines, intestinal occlusions, etc.).

In this report, the Marine Turtle Group France, which brings together the stakeholders of marine turtle conservation on the French territory, summarizes the data collected by different observation networks and care centers in mainland France and its overseas territories in order to evaluate the impact of marine debris on turtles, most of which are threatened with extinction.