INCIDENTAL CATCH OF MARINE TURTLES IN THE MEDITERRANEAN SEA: CAPTURES, MORTALITY, PRIORITIES

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INCIDENTAL CATCH OF MARINE TURTLES IN THE MEDITERRANEAN SEA:

CAPTURES, MORTALITY, PRIORITIES

By

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Executive summary

Three marine turtle species regularly occur in the Mediterranean basin: *Caretta caretta* (loggerhead turtle); *Chelonia mydas* (green turtle); and *Dermochelys coriacea* (leatherback turtle). Only the first two reproduce in the Mediterranean and they are globally listed as Endangered, while *Dermochelys coriacea* is listed as Critically Endangered in the IUCN Red List of Threatened Species.
Both loggerhead and green turtle populations are isolated from the Atlantic ones. However, high numbers of Atlantic loggerhead turtles enter the Mediterranean, distributing at least in the western and central areas.

Sea turtle populations in the eastern Mediterranean were severely exploited in the first half of the 20th century by fisheries specifically targeting turtles for trade. Nowadays, international trade in turtles is not a conservation issue in the Mediterranean. The harvest of eggs and adult females at nesting beaches, and the intentional harvest of turtles at sea are also not very important current issues too, thanks to the protection of these species through specific legislation. The two main current threats are the anthropogenic impact on nesting sites and interaction with fisheries.

The impact of fishing on sea turtles is a very complex issue, with many parameters involved, resulting in great uncertainty regarding the number of turtles caught, mortality, and possible conservation measures.
In recent years, many studies have been carried out on sea turtle bycatch, and these data are here reviewed in order to suggest conservation priorities at regional level.

Catch rates and fleet data were used to estimate total number of captures per year at local scale and then at regional level, through a conservative approach, i.e. preferring underestimates to overestimates. Conservative values of mortality, based on the best available knowledge, were applied to estimate the total number of turtles dying per year as a consequence of fishery interaction. Several information gaps in catch rates and country fleet are further reason to consider these estimates as conservative.

Four fishing gear were considered in this analysis, as they appear to be the most relevant ones. Bottom trawlers are estimated to cause over 40,000 captures per year, with probably more than 10,000 deaths, mainly in Italy, Tunisia, Croatia, Greece, Turkey, Egypt, and Libya, and possibly other countries. Pelagic longliners would have over 50,000 captures and 20,000 deaths, mainly in Spain, Morocco, Italy, Greece, Malta, Libya, and possibly other countries. For demersal longliners these figures are over 35,000 and 14,000 respectively, mainly in Tunisia, Libya, Greece, Turkey, Italy, Egypt, Morocco, and possibly other countries. Finally, over 30,000 captures and 16,000 deaths are estimated for set netters, mainly in Tunisia, Libya, Greece, Turkey, Cyprus, Croatia, Italy, Morocco, Egypt, France, and possibly other countries.

Although with a high degree of uncertainty, it is likely that in the Mediterranean sea turtle bycatch is high, over 150,000 per year, with a high number of deaths too, probably over 50,000 per year. Moreover, many others are killed intentionally and probably many are killed by ghost gear too.

Until population dynamics of Mediterranean populations necessary to understand the impact of such a mortality on the populations will be disclosed, under a precautionary approach mortality induced by fishing interaction should be assumed to be not sustainable and so conservation measures should be deemed as necessary.

Unfortunately, measures ready to be implemented are few, their implementation is not easy, and/or their positive effects are not assured. However, specific measures for mitigating the impact of demersal longline, set nets, and ghost fishing have not been even suggested yet.

Results indicate that those fishing gear suspected to cause the highest number of captures and deaths in the Mediterranean are used by small vessels (set nets, demersal longlines, part of pelagic longline). Moreover, implementation of measures such as modifications of the fishing gear are more feasible for few large industrial vessels than for thousands of small artisanal vessels, so perhaps a new kind of strategy should be developed.

Proposed priority actions are:

<u>Intentional killing</u>

- Assess the drivers of intentional killing and reduce it (Egypt, Greece, Cyprus, Syria, Tunisia, Turkey)

<u>Pelagic longline</u>

- Set up fishing area management/closure (Spain)
- Ban lightsticks attractive for turtles (Mediterranean)
- Where squids are used as a bait, promote change to mackerels
- Reduce post-release mortality through awareness campaigns (Spain, Italy, Morocco, Greece, Malta, Libya. Tunisia)
- Test large different hooks (e.g. large circle hooks) and deep hooks (Italy, Morocco, Greece, Malta, Tunisia, Libya, Tunisia)
- Test restriction to night time (Spain, Italy, Morocco, Greece, Malta, Libya)
- Investigate possible spatial differences in catch rates among fishing areas suitable for an area management approach (Italy, Morocco, Greece, Malta, Libya, Tunisia)

<u>Demersal longline and set net (artisanal fisheries)</u>

- Test different hooks (e.g. circle hooks) in demersal longline (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, and Italy)
- Reduce post-release mortality in demersal longline through awareness campaigns (pelagic longline: Spain, Italy, Morocco, Greece, Malta, Libya. Tunisia; demersal longline: Tunisia, Libya, Greece, Turkey)
- Investigate measures to reduce catch rate and mortality rate in demersal longlines (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, and Italy) and set nets (Tunisia, Libya, Greece, Turkey).
- Assess captures and mortality in demersal longlines (Libya, Greece, Turkey, Egypt, Morocco, and Italy) and set nets (Tunisia, Libya, Greece, Turkey).
- Elaborate strategies to address turtle bycatch and fishery management in artisanal fisheries (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, Cyprus, Croatia)

<u>Bottom trawl</u>

- Reduce post-release mortality in bottom trawl through awareness campaigns (Italy, Tunisia, Croatia, Greece, Turkey, Egypt, Libya)
- Test a TED type suitable for Mediterranean target species (Italy, Tunisia, Croatia, Greece, Turkey, Egypt, Libya)
- Assess mortality rate and associated fishing parameters in bottom trawlers, useful to indicate the best mitigating measures (e.g. TED, awareness campaign) (Italy, Tunisia, Croatia, Turkey¸ Egypt, Greece, Libya).

<u>General</u>

- Establish marine protected areas around major nesting sites (Greece, Turkey, Cyprus, Libya)
- Promote ecosystem-based management of fisheries, especially with small-scale fisheries (Mediterranean)
- Promote reduction of fishing effort, including illegal fishing (Mediterranean)
- Collect biological data and develop population models to understand the impact of bycatch on Mediterranean sea turtles (Mediterranean)
- Develop and implement national marine turtles management and conservation plans

1. Introduction

The Mediterranean Sea is a virtually enclosed basin connected to the Atlantic through the 12 kilometer-wide Strait of Gibraltar. There is 46,000 km of coastline, of which a significant stretch belongs to islands. It is surrounded by 21 countries with different cultures. In all, about 150 million people live on the Mediterranean coast. It is affected by intensive fishing at sea and by intensive and increasing tourism (about 170 million tourists per year) especially in the summer months, which is the marine turtle nesting period too.

Generally speaking, marine turtles are threatened by a large number of human activities, both on land and at sea, making their conservation a great challenge. Historically, the main factor impacting populations globally was the harvest of eggs and turtles for consumption and trade. Fortunately, this threat has been greatly reduced in many areas by legal protection at international and national level, although the problem has not been completely eliminated. For instance, turtles are still killed for consumption in some places.

In the Mediterranean, severe exploitation occurred in the first half of the 20^{th} century by fisheries specifically targeting turtles off the coast of (what are now) Israel and Palestine, and in the Iskenderun Bay in Turkey. Turtles were sold to the United Kingdom and Egypt (Sella, 1982). Nowadays, international trade in turtles is not a conservation issue in the Mediterranean. The harvest of eggs and adult females at nesting beaches, and the intentional harvest of turtles at sea are also not very important current issues too, thanks to the protection of these species through specific legislation.

Much effort is now allocated on sea turtle conservation in the region, by NGOs, governments, research institutes. An Action Plan for the conservation of sea turtles in the Mediterranean was issued in the framework of the Barcelona Convention (RAC/SPA, 2001) and WWF developed an Action Plan too (WWF, 2005).

Nowadays, there are two main issues for sea turtle conservation in the Mediterranean the anthropogenic impact on nesting sites, and interaction with fisheries. There are several others (e.g. pollution, collision with boats, climate change, and predation by species with populations increased thanks to human resources like waste), which may affect turtle populations, but at present they are seen to have secondary importance.

Regarding nesting sites, they are basically threatened by direct or indirect consequences of tourism pressure. In fact, a large number of tourists visit the Mediterranean coastline every year, and the associated habitat degradation is an important threat to nesting sites. Tourist infrastructures, the modification of coastline, sand extraction and other factors may physically destroy a nesting beach, and intensive human activity during the nesting season (e.g. mechanical cleaning, light and noise pollution, chairs and umbrellas, night frequentation, collision with recreational boats) may interfere with the nesting process, the incubation of eggs, and the movement of hatchlings to the sea. Moreover, wild canids, feral/domestic dogs, and seagulls, whose populations benefit from human presence, prey on turtle nests and hatchlings.

In addition to protection on land in order to avoid the physical destruction of the nesting site, it is important that protection should be granted to the nearby marine area – at least during the reproductive season, in order to avoid human activities affecting adults and hatchlings at sea. The protection status of the major nesting sites is given in Table 4-1. Of the 76 Marine Protected Areas in the Mediterranean, only one includes a major turtle nesting site – Laganas Bay in Zakynthos (Mabile and Piante, 2005).

Regarding interaction with fisheries, in the Mediterranean there is no specific fishery or type of fishing gear that directly targets marine turtles. However, a large number of individuals are captured as by-catch by fishing gear targeting other species. A clue of the importance of fishing-induced mortality

is the high proportions of turtles stranding ashore with evidence of interaction with fishing gear (e.g. Egypt: Clarke et al., 2000; Greece: Kavvadia et al., 2006; Italy: Casale et al., in press a; Spain : Tomas et al., 2006)
In some fisheries, intentional killing for meat is associated with these captures and turtles are consumed directly by fishermen or traded at local markets. In some fisheries, intentional injuring or killing for other reasons is an additional serious threat.
Naturally, destructive and often illegal practices such as dynamite fishing may represent an important threat especially at coastal zones near nesting sites.

Understanding the current turtle bycatch levels, consequent mortality, the most involved areas and countries, and the most relevant parameters is fundamental for elaborating appropriate conservation measures.
Unfortunately, in the Mediterranean this is particularly difficult because of several constraints. The high number of countries makes it difficult to standardize different fishing gears, fishery statistics systems, and databases; and also to collect all data from different sources. The small scale or "artisanal" nature of most Mediterranean vessels makes it difficult even to take a census of them. The high number of small vessels implies a high heterogeneity in the technical features of fishing gear and makes it difficult to study interaction on a vessel basis.
At present there is much information about sea turtle bycatch in the Mediterranean, but the above heterogeneity requires to analyze data at the smallest geographical scale as possible.
Three reviews provided an overview of sea turtle bycatch in the Mediterranean. The first one (Gerosa and Casale, 1999) considered the most important fishing gear, the second (Caminas, 2004) discussed the relative importance of fishing impact on Mediterranean populations, while the third considered only pelagic longline (Lewison et al., 2004).

With much more information and new insights made available in the recent period, the aim of the present report is to provide an updated overview and estimation of turtle bycatch and consequent mortality in the Mediterranean, and to review current conservation options for mitigating this threat, attempting prioritization of measures and areas.

2. Relevant parameters for assessing the impact of fishing activity on marine turtle populations

2.1. Number of captures

The number of turtles caught can be obtained through a census, if all fishermen voluntary record the captures in their logbooks or if independent observers are onboard in every trip. However, both these conditions are rather unrealistic, for problem of compliance, reliability, and coverage (i.e. research effort).

The alternative way is to estimate the number of captures (C) from two parameters: **fishing effort** (FE) and **catch rate** (CR):

C = CR * FE

However, it should be taken into consideration that:

a) the catch rates obtained from the field should be based on the same unit of fishing effort of the total fishing effort
b) both catch rates and fishing effort may vary according to the port/area or season, so that statistical stratification may be needed
c) attention should be given to any technical difference among gear classified under the same general name, because these differences can affect catch rate and if so they should be considered different fishing gear

In conclusion, necessary data are:

- fishing effort (e.g. no. of vessels, fishing days, standardized fishing effort) for any distinguishable fishing gear, area, season
- turtle catch rate (e.g. turtle/vessels-year, turtle/vessel-days, turtle/standardized fishing effort) for any distinguishable fishing gear, area, season

It should be taken into account that the result is the number of captures and not the number of individual turtles caught, because an individual turtle can be captured more than one time.

2.2. Number of deaths

The number of captures as such is of little use for conservation. The relevant information is the harvest induced by fishing activity, i.e. the number of turtles which die due to the fishing activity. The number of **Deaths** (D) can be calculated from the number of captures (C) if the **mortality rate** (MR) due to the interaction is known:

D = C * MR

Since mortality rates differ among fishing gear, any speculation about the relative impact of different fishing gear based just on number of captures is intrinsically wrong and should be avoided.

Mortality rates should be estimated for each fishing gear and for any variation in parameters that can affect mortality (e.g. turtle size, temperature, tow duration, fishermen behavior).

Basically, two sources of mortality can be identified:

- mortality induced by the fishing gear
- mortality induced by fishermen (intentional killing)

2.2.1. Gear-induced mortality

For convenience gear-induced mortality can be divided into two categories: **at-Retrieval Mortality Rate** (RMR; mortality observed at the gear retrieval; also known as direct mortality) and **Post-release Mortality Rate** (PMR; mortality occurring after the turtle has been released alive; also known as indirect mortality).

Since PMR acts only on turtles surviving RMR, the two cannot be simply added, and the overall gear-induced mortality rate (GMR) should be calculated as:

GMR = RMR + (1 - RMR) * PMR

2.2.2. Intentional killing

Intentional killing may be due to several reasons: antagonism, superstition, meat consumption or trade. Mortality due to intentional killing **(Intentional Mortality Rate**, IMR) can vary. In the worst case, it can make the overall mortality rate (MR) up to 100%.

MR = RMR + IMR + (1 - RMR - IMR) * PMR

2.3. Affected part of the population

Although it is the basic relevant information for conservation, even the number of deaths is not enough for assessing the overall impact on the population or the relative impact of different fishing gear. This is because turtles of different size/age are represented differently in the population (the highest numbers are in the smaller/younger size classes) and have a different reproductive value (the larger/older the turtle, the higher its reproductive value; e.g. Wallace et al., 2008). The effect of changes in stage-specific survival rate on the population growth increases from eggs and hatchlings, to small juveniles in the oceanic stage, to large juveniles and adults in the neritic stage (Heppell, 1998). Although this ranking can be affected by stage duration (the longer the stage, the higher its contribution; Heppell et al., 2003), it is likely to be particularly appropriate in the Mediterranean, where turtles recruit into the neritic habitats at a small size, suggesting relatively short pelagic and long benthic/pelagic stages (Casale et al., in press b; Lazar et al., in press).

Also the sex can be an important parameter: often sex ratios are skewed, males and females differ in frequency of reproduction, etc.; as a consequence, a turtle may have a different reproductive value according to the sex.

2.4. Effect on population growth

The final aim of all the assessment process described above is to understand how the fishing activity affects the populations, in terms of probability of extinction within a certain period. For this aim, the harvest induced by fishing should be included in a general model of population dynamics of the concerned population. Unfortunately, population dynamics is not well understood yet, due to the limited knowledge available on important parameters such as natural survival probability, age at maturity, duration of different life stages, sex ratio. As a consequence, predictive models have a high degree of uncertainty (e.g. Heppell et al., 2003); however, they can be helpful for understanding the relative importance of different fishing gear for their effect on population growth (e.g. Wallace et al., 2008).

3. Fishing gear, parameters, and mitigating measures

Most fishing gear can capture sea turtles, including those gear most widespread and with the highest fishing effort. However, the capture is caused and affected by biological and technical parameters that differ greatly among different fishing gear, so that it is important firstly to define the different fishing gear and to describe those technical or operational parameters involved in the capture of sea turtles.

Among all the existent fishing gear (see Nedelec and Prado, 1990), information is here given for six of them, belonging to three main categories: trawls (nets towed by boats), longlines (lines with baited hooks left at sea), nets (left at sea). These are among the most used fishing gear and the ones with evidence of interaction with sea turtles.

3.1. Bottom and Midwater trawls

Trawls consists in nets that are towed by one or two boats. The net has a cone shape, with a large **opening** or "mouth" where, thanks to the movement due to the towing boat, the target (and non-target) species enter and are collected at the opposite and small end of the net (**codend** or bag). If the net is towed by a single boat, the horizontal spread of the net is obtained by a beam or by two heavy otter boards at the sides that are in touch with the sea bottom and tend to diverge externally as a consequence of their running over the sea bottom. Alternatively the net can be kept open by two boats, each towing one of the two towing wires. Apart beam trawls, the bottom and top ropes surrounding the opening (called **groundrope** and **headrope**), have weights and floats respectively that provide the vertical spread of the net. Mesh size usually decreases from the front to the codend.

Two main categories are recognized. **Bottom trawl** nets (Fig. 3-1) operate in touch with the sea bottom and capture demersal or semi-demersal organisms. **Mid-water trawl** (or pelagic) nets (Fig. 3-2) do not operate in touch with the sea bottom and they capture pelagic fish.

In a single **fishing trip**, there can be several **tows** (single fishing operations starting with the release of the net in the sea and ending with its retrieval onboard).

Many parameters can vary among different fisheries, vessels from the same fishery, and even among trips or single tows of the same vessel (e.g. size of the net, operational depth, speed, tow duration, time of the day, season) and they may affect the different aspects related to turtle catch.

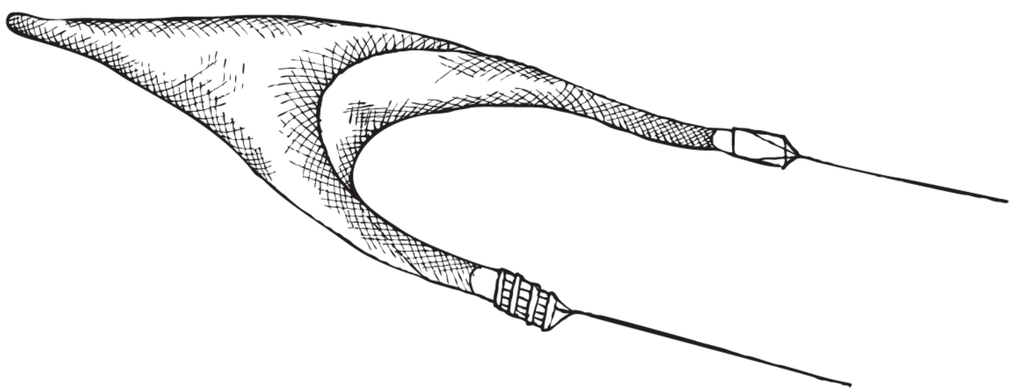

Fig. 3-1. Bottom trawl net.

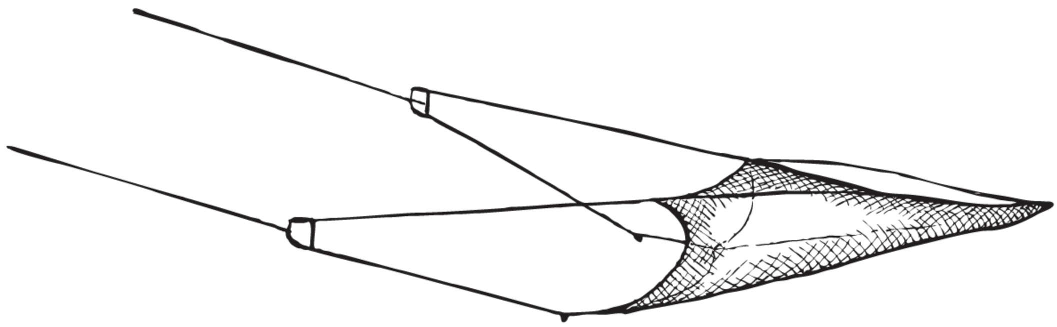

Fig. 3-2. Midwater trawl net.

3.1.1. Parameters affecting catch rate

Part of these parameters are related to fishing operations and theoretically (but rarely in practice) can be included in the assessment of fishing effort so to allow a full standardization of catch rates. If they are not included, they affect partially-standardized catch rates. Other parameters are more related to turtle biology and affect turtle capture and catch rates.

3.1.1.1. Fishing parameters

Obviously, the number of turtles captured is affected by the fishing effort or more in general by the "capture capability". For instance, larger net openings probably are better in capturing turtles than smaller ones, longer or faster tows have more chances to encounter a turtle than shorter ones, and so on.

This is the reason why standardized catch rates should be calculated, as an attempt to standardize the number of captures per units of fishing effort. However, several different units of fishing effort can be used. For instance, in an increasing attempt to consider as many parameters as possible and have a better standardization: vessel-year, vessel-trip, vessel-day, tow, tow*duration, tow*duration*headrope, tow*duration*headrope*speed. GFCM (www.gfcm.org) standardization considers GT*Days, GT*Hours, and KW*Days, where GT is Gross Tonnage (a measure of ship volume) and KW Kilowatts (engine power). Thus, depending on the unit of effort adopted, the other parameters not included in it may affect catch rates. For instance, turtles/vessel-year can vary among different vessels which fish for different numbers of days in a year, or make different numbers of tows, or tow at different speeds, etc. For this reason, the more parameters are included in a standardized catch rate, the more reliable is the comparison among different data sets.

3.1.1.2. Areas and depths

Sea turtles are not uniformly distributed. So catch rates will be higher is areas where turtles concentrate. Moreover, within these areas, turtle occurrence varies according to the depth: species like *Caretta caretta* and *Chelonia mydas* (the two most abundant in the Mediterranean) do not dive deep, with maximum recorded depths of 110 m and 233 m respectively (Lutcavage and Lutz, 1997). Accordingly, most captures by trawl were observed or inferred in shallow waters, on sea bottoms less than 50 m or even 20 m deep (e.g. Epperly et al., 1995; Hare, 1991; Caillouet et al., 1991; Bradai, 1994).

3.1.1.3. Season and time of the day

Sea turtles can cover long distances moving from one area to another, depending on factors like temperature, food availability, reproduction. So the abundance of turtles, and consequently the catch rate, can vary according to the season: winter/summer migrations (e.g. Musick and Limpus, 1997), reproductive migrations (e.g. Broderick et al., 2007), etc.

Turtles may be in the area but their activity differs temporally, due to circadian rhythms (e.g. Rice and Balazs, in press) or temperature changes, so that catch rate can vary according to the season or the time of the day.

3.1.2. Parameters affecting mortality rate

The main cause of mortality induced by trawling is drowning due to forced apnea. Turtles may be found in three conditions: healthy, dead (at-Retrieval Mortality Rate, RMR), and comatose. Comatose turtles are not able to swim and are likely to drown if released at sea in this state (Post-release Mortality Rate, PMR).

Four main factors (see below) can affect RMR and PMR: tow duration, fishing effort, temperature, and turtle size. An additional cause of mortality may be the physical damage due to the weight of the other catch while the turtle is in the in the net (Hare, 1991).

3.1.2.1. Tow duration

Obviously, the longer the duration of the forced apnea, the higher the expected mortality. It should be taken into account that a forced apnea cannot be compared with a voluntary apnea, which can last for long under normal conditions (see Hochscheid et al., 2007 for a review), because to be captured in a net which moves rapidly in the water and is full of other material is cause of stress for the turtle and also induces the turtle to a high escaping effort. Accordingly, a higher concentration of lactic acid was observed in turtles caught by trawlers than in turtles which experiences the same period of forced apnea but in captive conditions (Stabenau et al., 1991). The increase of concentration of lactic acid could be as high as 10-80 times (Lutz and Dunbar-Coober, 1987).

The forced apnea begins with the turtles entering the net underwater, and ends with the turtle being brought on the deck with all the other catch. Naturally the turtle could have already spent some time in voluntary apnea when it is captured by the net. Tow duration is longer than the real forced apnea, because (i) the net takes some time to fall to the sea bottom and to start working properly, (ii) the turtle can be captured at any time during the tow. However, tow duration is the best approximation of the potential duration of forced apnea that is possible to obtain while monitoring fishing operations. Sasso and Epperly (2006) estimated a mortality rate below 1% for tow durations shorter that 10 minutes, but rapidly increasing to 50-100% for tows longer than 60 minutes.

3.1.2.2. Fishing effort

After the capture, a turtle has a high blood acidosis and Lutz and Dunbar-Coober (1987) estimated that restoring normal values can take at least 20 hours. If the fishing effort in the area is very high, an individual turtle can be captured multiple times with an interval too short to restore all the physiological parameters. Epperly et al. (1995) suggested that this is the reason of the high proportion of turtles found in comatose state in areas with high fishing effort. Stabenau and Vietti (2003) specifically investigated the physiological consequences of multiple captures by trawl nest with TED (see § 3.1.4.2.), and observed a faster recovery then that above, although in this study forced apnea was limited to just 7.5 minutes (they investigated the effect of the short forced apnea before exiting the net thank to the TED) while it was probably longer in the normal tows of the study by Lutz and Dunbar-Coober (1987). Other parameters such as temperature and turtle size may affect the recovery rate and explain the differences between these two studies. Thus, the effect of multiple captures caused by high fishing effort is uncertain but should be taken into account.

3.1.2.3. Temperature

As in all poikilotherms, in turtles higher temperatures induce higher metabolic rate and oxygen consumption (Lutz et al., 1989). So, tolerance to apnea would be expected to decrease with increasing temperatures. However, Sasso and Epperly (2006) reported higher mortality in winter than in summer, and suggested that low temperatures may have other physiological effects that reduce tolerance to apnea.

3.1.2.4. Turtle size

There are indications that larger turtles are more resistant to forced apnea (Hillestad et al., 1982), as a consequence of their greater apnea capacity under natural conditions. Therefore, under the same conditions of tow duration, multiple captures and temperature, it is likely that small turtles suffer a higher mortality rate than large ones.

3.1.3. Parameters affecting the part of the population caught

Trawlers fishing close to the sea bottom (bottom trawlers and in some cases mid-water trawlers too) capture turtles which feed on benthic preys. Turtles like *Caretta caretta* are more likely to feed on benthic preys when larger than when smaller (e.g. Casale et al., in press b). This is why trawlers fishing close to the sea bottom capture turtles of a relatively large size, although this size varies according to the area and population: in the north western Atlantic minimum observed sizes were around 48 cm CCL (Kontos and Webster, 1985; Epperly et al, 1995) while in the Mediterranean minimum observed sizes were smaller (22-49.4 cm CCL; Laurent et al., 1996; Laurent, 1996; Casale et al., 2004; Casale et al., 2007a; Lazar et al., in press).

However, there are not specific and variable fishing parameters that select turtles according to size.

3.1.4. Possible mitigating measures

As seen above (§ 2.), the number of deaths is function of three factors (fishing effort, catch rate, mortality rate) and so it can be reduced by reducing these factors, through the following approaches.

3.1.4.1. Reducing fishing effort

The number of turtles captured can be reduced by reducing the fishing effort (with unchanged catch rate and mortality rate). This includes an reduction of fishing effort as a whole (fleet, fishing days, etc.) or just restrictions in specific areas/season/time where/when turtles are more abundant (and the Catch Rates are higher).

3.1.4.2. Reducing catch rate

The number of turtles captured can be reduced by fishing gear modifications that reduce catch rates (with unchanged fishing effort and mortality rate). Only one solution of this kind has been developed (since 1980 in the USA): the Turtle Excluder Device (TED) (see Epperly, 2003 for a review). It consists in a grid placed in the net before the codend that allows small objects (including target species) to pass through the bars, while it diverges larger objects (including turtles) to an escaping door in the net. So, strictly speaking TEDs do not reduce catch rates, but rather they let most of captured turtles escape. However, the capture (even if very short) may still have some negative effects, although probably not lethal (Stabenau and Vietti, 2003).

Several models of TED have been developed, and mainly differ in material, shape, size and gap among the bars (Mitchell et al., 1995).

TED was developed for the shrimp fishery. Shrimps are small and easily pass through the TED grid in contrast to turtles, so reduction of turtle catch can be high (a 97% reduction is required for certifying a TED under USA regulation; Epperly, 2003) with negligible loss of catch. However, in case of larger target species, a significant loss of catch might occur.

Stranding records (Epperly and Teas, 2002; Lewison et al., 2003) do not show an evident reduction of turtle strandings since when TEDs have been made mandatory by law, or at least not as much as expected on the basis of the 97% reduction possible with the TED (Caillouet et al., 1996; Epperly, 2003; Lewison et al., 2003). It was suggested that such a discrepancy may be due to incorrect or no installation of TEDs (Caillouet et al., 1996; Lewison et al., 2003): TED implementation was difficult in the USA and required specific regulations and enforcement, with problem of compliance (Epperly, 2003).

3.1.4.3. Reducing mortality rate

Fishing operation and turtle handling procedures can reduce mortality rate (with unchanged fishing effort and catch rate).

Tow duration has a great effect on mortality (§ 3.2.2.1.), so shorter tow durations would result in lower mortality. However, shorter tow durations means more tows and so a greater work by the crew and by the engines (more setting and hauling operations). For this reasons compliance would be low, while enforcement is very difficult (Epperly, 2003). Thus, limiting tow duration does not seem to be a realistic solution.

Post-release mortality is due to the drowning of turtles in comatose condition (§ 3.2.2.) and can be even more important than at-retrieval mortality when comatose turtles are more than dead ones (e.g. Casale et al., 2004). This mortality can be greatly reduced if fishermen allow these turtles to recover on the deck before releasing them. However, this can require up to several hours and so can interfere with the work on board.

3.2. Pelagic and demersal longline

Longlines consist in a **main line** (usually nylon) to which secondary lines (**branchlines**) are attached. Each branchline ends with an **hook** carrying a **bait**. Drifting or pelagic longlines are not anchored and are kept relatively near the surface thanks to many **floats** regularly spaced along the gear and attached to secondary lines (**float line**) that can simply be one of the branchlines. Set or demersal longlines (Fig. 3-3) are anchored to the sea bottom by **weights** regularly spaced along the gear and attached to secondary lines (**weight line**) that can simply be one of the branchlines. The gear unit between two floats (pelagic longline) or weights (demersal longline) is called "**basket"**. In demersal longlines, the main line is kept in midwater by means of floats placed along the basket. Pelagic longline (Fig. 3-4) are usually longer then demersal longlines, and carry more branchlines (and hooks), usually more than one thousand. In a single **fishing trip**, there can be one or more **sets** (single fishing operations starting with the release of the gear in the sea and ending with its retrieval onboard). Target species of pelagic longline are pelagic fish such as swordfish, tuna, sharks, dolphin fish, while demersal longline catches demersal fish such as dentex, grouper, axillary seabream.

Many parameters can vary among different fisheries, vessels from the same fishery, and even among trips of the same vessel (e.g. shape and size of the hook; branchline length; distance between branchlines; number of branchlines in a basket; number of baskets; float/weight line length; type of float/weight; type and size of bait; presence of lightsticks; operational depth, due to some of these parameters) and they may affect the different aspects related to turtle catch.

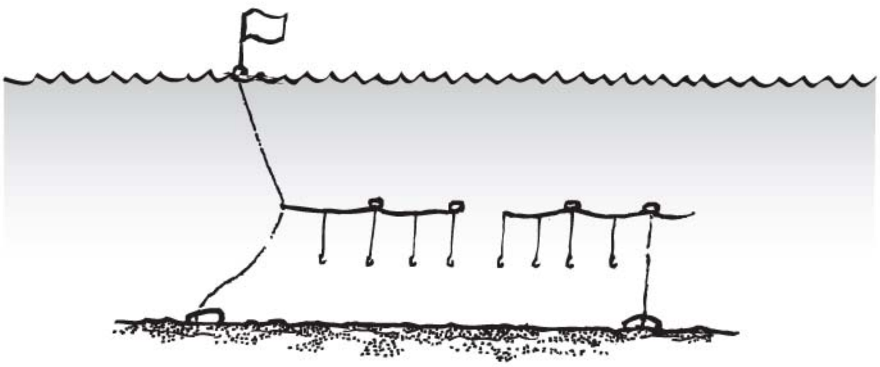

Fig. 3-3. Demersal longline.

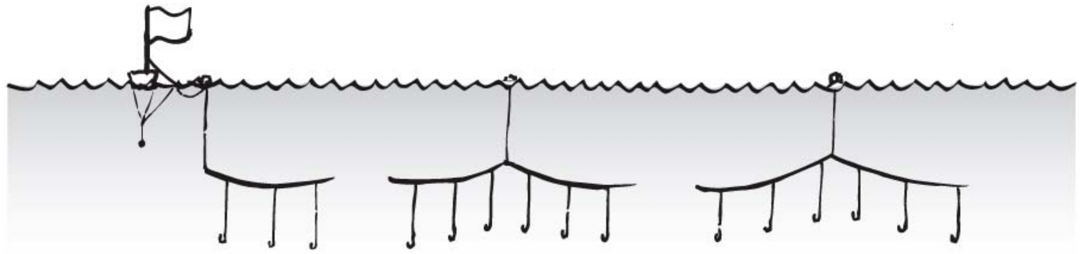

Fig. 3-4. Pelagic longline.

3.2.1. Parameters affecting catch rate

Part of these parameters are related to fishing operations and theoretically (but rarely in practice) can be included in the assessment of fishing effort so to allow a full standardization of catch rates. If they are not included, they affect partially-standardized catch rates. Other parameters are more related to turtle biology and affect turtle capture and catch rates.

3.2.1.1. Fishing parameters

Obviously, the number of turtles captured is affected by the fishing effort or more in general by the "capture capability". For instance, a longline with more hooks can potentially capture more turtles than one with less hooks. This is the reason of the unit of fishing effort commonly used to standardize effort for this fishing gear (1000 hooks), that represents the first basic standardization in comparison to other units such as vessel-year, vessel-trip, and vessel-day. GFCM (www.gfcm.org) standardization considers Hooks*Days, Hooks*Hours, and longline unit*Days/hours.

However, several other parameters can affect catch rate, so that a real standardization is very difficult to achieve. They can be ascribed to three main groups: hook, bait, and depth.

Hooks are produced by different manufacturers in many different models with different size and shape. The "anatomy" of a hook has several components. The point can be parallel to the shanker (a "J" hook) or perpendicular to the shanker (a "circle" hook) or can be in the between of these two. As a consequence, the gape between the point and the shank varies, and this can affect the chances of the turtle's ranphoteca to pass through and get engaged. Moreover it may affect the capacity of the turtle to disengage from the hook; for instance, circle hooks are known to hold the catch better than J hooks. The gape can be different, with the potential effects described above. The barb size and length can affect the capacity of the turtle to disengage. Usually the shank and the point are not on the same plain, but on plains with a difference of 10-25° (degree offset), in order to enhance the catch capability. Finally, the size of the hook (even within the same model) is an important factor: larger (wider) hooks are more difficult to swallow due to physical constraints of the turtle's mouth (Watson et al., 2003).

Baits of different species and sizes can be used, and this may affect turtle catch due to attractiveness, hook sheltering, difficulty to be ingested. For instance, turtle catch rate is lower with big mackerels (200-500 g) than with squid (150-300 g) (Watson et al., 2005).

In pelagic longline, the **hook depth** along the water column is a very important factor, because most turtle species do not dive deep. For instance, Polovina et al. (2003, 2004) observed that *Caretta caretta* and *Lepidochelys olivacea* spend 90% of their time at depths less than 40 m, and rarely dive deeper than 100 m. Hook depth is determined by different gear parameters, such as

branchline length; float line length; basket length (the more the distance between two floats, the wider the arch of the mainline, the deeper the hook at the center).
Some longlines have lightsticks, i.e. artificial lights that attract target species. Unfortunately, they attract turtles too, increasing catch rate (e.g. Kapantagakis, 2001; Wang et al., 2007)

3.2.1.2. Areas and depths
Sea turtles are not uniformly distributed. So catch rates are higher is areas where turtles concentrate. Moreover, within these areas, turtle occurrence varies according to the depth: species like *Caretta caretta* and *Chelonia mydas* (the two most abundant in the Mediterranean) do not dive deep, with maximum recorded depths of 110 m and 233 m respectively (Lutcavage and Lutz, 1997). As a consequence, demersal longlines can have different turtle catch rates according to the depth at which they are set.

3.2.1.3. Season and time of the day
Sea turtles can cover long distances moving from one area to another, depending to factors like temperature, food availability, reproduction. So the abundance of turtles, and consequently the catch rate, can vary according to the season: winter/summer migrations (e.g. Musick and Limpus, 1997), reproductive migrations (e.g. Broderick et al., 2007), etc.
Turtles may be in the area but their activity differs temporally, due to circadian rhythms (e.g. Rice and Balazs, in press) or temperature changes, so that catch rate can vary according to the season or the time of the day. For instance, Baez et al. (2007a) observed that most turtles are captured by pelagic longline during daylight.

3.2.2. Parameters affecting mortality rate
In turtles caught by longlines, mortality is due to lesions caused by the hook or the branchline (Casale et al., 2008a). Drowning can be a cause of mortality as well, whenever the structure of gear does not allow the turtle to surface and breath. This is more the case of demersal longlines that are anchored to the sea bottom, than of pelagic longlines that usually allow turtles to breath; in fact most of them are found alive at retrieval.
Although available information indicates that mortality rate induced by longlines is high (Casale et al., 2008a), good estimations are not yet available, due to the difficulty of taking into consideration all the parameters involved. Nevertheless, it is plausible that the following parameters affect mortality rate.

3.2.2.1. Depth and anchorage/weights
Since longlines are left in place for many hours, whenever the depth of the longline in the water column and weights or anchorages to the sea bottom impede the turtle to reach the surface to breath, drowning is very likely. This is usually the case for demersal longlines.

3.2.2.2. Hook size and shape
Larger hooks can cause larger injuries than smaller hooks, so it is plausible that in the same conditions (e.g. tract of the digestive tract) they can induce a higher mortality rate.
The shape of the hook (e.g. the direction of the point or the degree offset; see § 3.2.1.1.), can affect the probability of the hook to perforate the tissue, so it may affect the mortality rate.
Circle hooks are thought by several researchers to reduce PMR in comparison with J hooks, because they tend to engage in the mouth instead of being swallowed deeper (Read, 2007). However, this supposed lower PMR in turtles with a circle hook in the mouth then circle hooks in other positions or then J hooks, has not been demonstrated yet.

3.2.2.3. Hook position
Injuries in different parts of the digestive tract (mouth, oesophagus, stomach, intestine) probably induce different mortality rates, also because of the different organs that can be damaged in addition to the digestive tract. Unfortunately this has not been properly assessed, although it is suggested by available observations (Casale et al., 2008a).

3.2.2.4. Branchline
A relatively short piece of branchline (50-100 cm) left on the turtle at release can easily

cause death if ingested (Casale et al., 2008a), and probably this PMR can be reduced if fishermen leave on turtles shorter lines.

3.2.3. Parameters affecting the part of the population caught

3.2.3.1. Area and fishing gear

Demersal longlines are typically used in shallow waters of the neritic zone while pelagic longlines are typically used in deeper waters, although there are exceptions to this general rule. For this reasons, the former is likely to capture mainly large turtles feeding on benthic preys, while the latter is likely to capture mainly small turtles feeding on pelagic preys.

3.2.3.2. Hook and bait size

Mouth size limits the size of objects that can be swallowed by a turtle. For this reason, the larger the hooks, the larger the turtles that are able to swallow it (Watson et al., 2003). This is probably the reason why large circle hooks show lower catch rates than small J hooks (Watson et al., 2005) (see 3.2.1.1.). Also the bait size may have this effect: mackerel (200-500 g) show a lower catch rate than squid (150-300 g) (Watson et al., 2005).

3.2.4. Possible mitigating measures

As seen above (§ 2.), the number of deaths is function of three factors (fishing effort, catch rate, mortality rate) and so it can be reduced by reducing these factors. Some of the most promising measures have been reviewed by Gilman et al. (2006).

3.2.4.1. Reducing fishing effort

The number of turtles captured can be reduced by reducing the fishing effort (with unchanged catch rate and mortality rate). This includes a <u>reduction of fishing effort as a whole</u> (fleet, fishing days, etc.) or just restrictions in <u>specific areas/season/time</u> where/when turtles are more abundant (see Gilman et al., 2006; Baez et al., 2007a,b).

3.2.4.2. Reducing catch rate

The number of turtles captured can be reduced by <u>fishing gear modifications</u> that reduce catch rates (with unchanged fishing effort and mortality rate).

<u>Large hooks.</u> In the north-west Atlantic pelagic longline fishery, using large circle hooks (18/0; 0-10° offset; 5.1-cm wide) instead of J-hooks (9/0; 25° offset; 4.1-cm wide) reduced the catch rate of loggerhead turtles (*Caretta caretta*) by 86% (Watson et al., 2005). Although the different shape and offset used represent a confounding factor, tests in captivity (Watson et al., 2003) and comparison with other tests in the field using other hook sizes (reviewed by Gilman et al., 2006) strongly suggests that this catch rate reduction was due to the hook size.
Naturally, this effect depends on the size of turtles occurring in the fishing area, so that the increase on hook size necessary to decrease turtle catch rate may vary according to the area.
For fisheries targeting small species and so using small hooks (for instance demersal longliners), this measure might not be feasible.

<u>Deep hooks.</u> Although direct evidence is lacking, due to confounding factors (see Gilman et al., 2006), setting hooks deeper in the water column should reduce the catch rate, because turtles spend more time near the surface. For instance, Polovina et al. (2003, 2004) reported that loggerhead turtles spend 90% of their time at depths less than 40 m, and rarely dive deeper than 100 m..
Naturally, this measure is not feasible for demersal longline.

<u>Mackerel bait</u>. In the north-west Atlantic pelagic longline fishery, using mackerels instead of squids as bait on J-hooks (9/0; 25° offset; 4.1-cm wide) reduced the catch rate of loggerhead turtles (*Caretta caretta*) and leatherback turtles (*Dermochelys coriacea*) by 71% and 66% respectively (Watson et al., 2005). It is possible that the larger size (200-500 g) and strength of mackerels make them more difficult to be swallowed by loggerhead turtles than the smaller (150-300 g) and softer squids. Accordingly, no further catch rate reduction was observed when using mackerels on large hooks (circle hooks 18/0) (reviewed by Gilman et al., 2006). Differently, leatherback turtles do not swallow the hook but get hooked externally.

In this case, mackerel would be a better physical shelter of the hook point than squid.

Circle hooks. In the north-west Atlantic pelagic longline fishery, using circle hooks (18/0; 0-10° offset; 5.1-cm wide) instead of J-hooks (9/0; 25° offset; 4.1-cm wide) reduced the catch rate of leatherback turtles (*Dermochelys coriacea*) by 57% (Watson et al., 2005). Because leatherback turtles are hooked externally, probably the shape of circle hooks (points is directed inwards) is the key factor. Differently, for the other turtle species (including loggerhead turtles) that are hooked internally, the shape probably does not affect the catch rate (see Gilman et al., 2006).

Lightsticks.
Laboratory tests showed that loggerhead turtles are attracted by a wide light spectrum (from blue to orange) produced by lightsticks used in longline fisheries (Wang et al., 2007). Accordingly, lightsticks were observed to increase turtle catch rate in the field (e.g. Kapantagakis, 2001).
So, removing them where already used and stopping their further diffusion among the longline fisheries would reduce present or potential catch rates.

3.2.4.3. Reducing mortality rate

Awareness campaigns can be designed to inform fishermen about turtle handling procedures by fishermen that can reduce the post-release mortality rate (with unchanged fishing effort and catch rate) (e.g. Gerosa and Aureggi, 2001). First, fishermen can cut the branchline close to the turtle's mouth. In fact, a relatively short piece of branchline (50-100 cm) left on the turtle at release can easily cause death if ingested (Casale et al., 2008a). Second, fishermen can remove hooks that are in easily accessible positions such as the mouth. This however can be difficult with some types of hooks, for instance circle hooks.

Although circle hooks have been suggested to induce a lower mortality rate than J hooks because they are more likely to catch the turtle in the mouth (Gilman et al., 2006), at present there are no information on turtle mortality due to hooks in different positions in the body to support this assumption. Indeed, circle hooks are well known to hold better, since the circular shape makes it difficult to disengage. If so, a circle hook in the mouth could compromise the turtle's fine-scale movements of mouth closure that are involved in olfactive and feeding performances (Hochscheid et al., 2005). Therefore, at the present state of knowledge, circle hooks can reduce mortality only if fishermen have adopted the above handling procedures and remove the hooks from turtles' mouth. Naturally, it cannot be assumed that the use of circle hooks is always associated to correct handling procedures. So circle hooks should not be assumed to reduce mortality *per se*.

3.3. Drifting and set net

These are nets set vertically in the water column and may vary greatly in **length, height,** and **mesh size**.
Drifting nets (Fig. 3-5) are made of one layer (gillnet) several kilometers long, several meters high, with a relatively large mesh size suitable for catching large pelagic fish (like swordfish, tuna, shark) in the open sea. They are kept near the surface by **floats** on the top line and are kept vertical by **weights** at the bottom line.
Set nets are smaller (hundreds of meters long and few meters high), with a relatively small mesh size, suitable for catching small demersal fish in costal waters. They can be made by a single layer (gillnet) (Fig. 3-6) or by three layers (trammel net), the two external ones with larger mesh size and the internal one with smaller mesh size (Fig. 3-7). These nets are anchored and kept near to the sea bottom by **weights** at the bottom line and are kept vertical by **floats** on the top line.

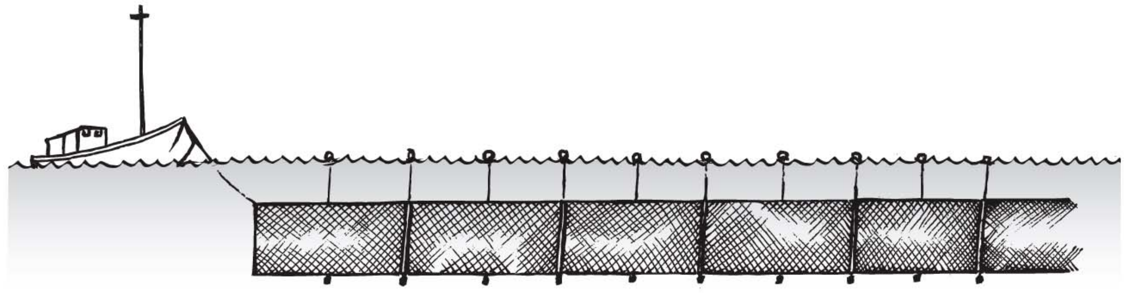

Fig. 3-5. Drifting net.

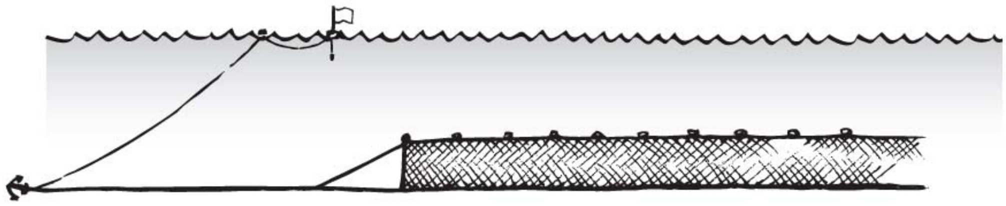

Fig. 3-6. Set net – gill net.

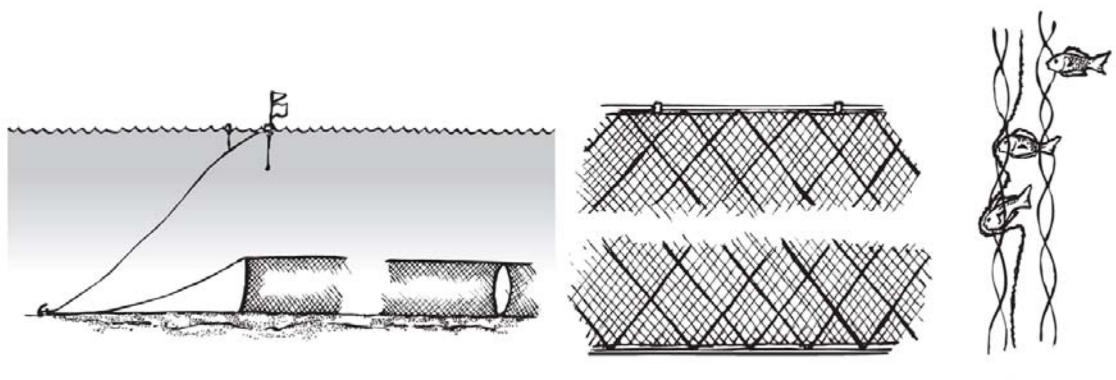

Fig. 3-7. Set net – Trammel net (three layers). When the fish pushes the internal small-mesh layer out of one of the external large-mesh layers, it gets entrapped in the resulting sac.

3.3.1. Parameters affecting catch rate

Part of these parameters are related to fishing operations and theoretically can be included in the assessment of fishing effort and this would allow a full standardization of catch rates. If they are not included, they affect partially-standardized catch rates. Other parameters are more related to turtle biology and affect turtle capture and catch rates.

3.3.1.1. Fishing parameters

Naturally, the number of turtles captured is affected by the fishing effort or more in general by the "capture capability". For instance, longer and/or higher nets probably catch more turtles than smaller ones.

This is the reason why standardizing the number of captures per units of fishing effort (in the broad sense as above) is desirable. Several different units of fishing effort can be used to calculate catch rates, depending on how many parameters are considered. For instance, from the less to the more comprehensive standardized fishing unit: vessel-year; vessel-day; set; km-set; km-day; km^2-set; km^2-day; km^2*h. GFCM (www.gfcm.org) standardization considers Net length*Days, Surface*Days.

Thus, depending on the unit of effort adopted, the other parameters not included in it may affect catch rates. For instance, turtles/vessel-year can vary among different vessels which fish for different numbers of days in a year, or make different numbers of set, or deploy nets of different length or height, etc. For this reason, the more parameters are included in a standardized catch rate, the more reliable is the comparison among different data sets.

3.3.1.2. Areas and depths

Sea turtles are not uniformly distributed. So catch rates may be higher is areas where turtles concentrate. Moreover, within these areas, turtle occurrence varies according to the depth: species like *Caretta caretta* and *Chelonia mydas* (the two most abundant in the Mediterranean) do not dive deep, with maximum recorded depths of 110 m and 233 m respectively (Lutcavage and Lutz, 1997). As a consequence, set nets can have different turtle catch rates according to the depth at which they are set.

3.3.1.3. Season and time of the day

Sea turtles can cover long distances moving from one area to another, depending to factors like temperature, food availability, reproduction. So the abundance of turtles, and consequently the catch rate, can vary according to the season: winter/summer migrations (e.g. Musick and Limpus, 1997), reproductive migrations (e.g. Broderick et al., 2007), etc.

Turtles may be in the area but their activity differs temporally, due to circadian rhythms (e.g. Rice and Balazs, in press) or temperature changes, so that catch rate can vary according to the season or the time of the day.

3.3.2. Parameters affecting mortality rate

The main cause of mortality induced by nets is drowning due to forced apnea. In this respect, the possibility for the captured turtle to breath (fishing depth, net height or other characteristics) is very important: set nets (close to the sea bottom) are intrinsically more harmful than driftnets (close to the sea surface). The fishing duration may also play a role, but unfortunately these nets are left at sea for many hours, so well beyond the tolerance range of turtles.

3.3.3. Parameters affecting the part of the population caught

Set nets are typically used in shallow waters of the neritic zone while drifting nets are used in deeper waters. For this reasons, the former is likely to capture larger turtles feeding on benthic preys, while the latter is likely to capture small turtles feeding on pelagic preys.

3.3.4. Possible mitigating measures

As seen above (§ 2.), the number of deaths is function of three factors (fishing effort, catch rate, mortality rate) and so it can be reduced by reducing these factors.

3.3.4.1. Reducing fishing effort

The number of turtles captured can be reduced by reducing the fishing effort (with unchanged catch rate and mortality rate). This includes a reduction of fishing effort as a whole (fleet, fishing days, etc.) or just restrictions in specific areas/season/time where/when turtles are more abundant.

3.3.4.2. Reducing catch rate

Information not available.

3.3.4.3. Reducing mortality rate

Information not available.

4. The marine turtles in the Mediterranean Sea

Three marine turtle species regularly occur in the Mediterranean basin: *Caretta caretta* (loggerhead turtle); *Chelonia mydas* (green turtle); and *Dermochelys coriacea* (leatherback turtle). Only the first two reproduce in the Mediterranean. Both species are globally listed as Endangered, while *Dermochelys coriacea* is listed as Critically Endangered in the IUCN Red List of Threatened Species.

Nesting sites are usually ranked in importance by the number of nests laid. Here they are classified as 'major' (> 70 nests/yr, Table 4-1) and 'minor' (< 70 nests/yr). This does not mean that minor nesting sites are not important. There are many known minor sites and probably many other minor sites that are as yet unknown, whose overall contribution in terms of hatchling production is certainly important. They can also contribute to population stability in other ways, such as a providing hatchlings of a different sex ratio, genetic diversity, or by acting as 'stepping stones', allowing male-mediated genetic flow between distant colonies (Carreras et al., 2007).

4.1. *Caretta caretta* (loggerhead turtle)

Caretta caretta has a worldwide distribution, frequenting tropical and temperate zones and oceanic and shallow costal waters. Information covering data until 1999 has recently been reviewed for the Mediterranean (Margaritoulis et al., 2003a). Genetic divergence indicates a degree of isolation from the Atlantic populations (Laurent et al., 1998; Carreras et al., 2006a). Thus, specific attention and conservation initiatives are required to safeguard the presence of this species in the Mediterranean.

4.1.1. Nesting sites

Nesting in the western Mediterranean is unusual. Almost all nests are found in the eastern basin, primarily in Greece, Libya, Turkey and Cyprus (Figure 4-1, Table 4-1) and, to a lesser extent, in other countries, such as Lebanon, Israel and Tunisia. The total number of nests in the Mediterranean is unknown, because only preliminary surveys were carried out in Libya. These were single surveys (i.e. one passage only, making it impossible to assess the total number of nests dug during the whole nesting season) covering only 31.6 percent of the sandy coast. These surveys suggested a greater number of nests in Libya than in Turkey and Cyprus and perhaps an equal or slightly higher number than in Greece (Laurent et al., 1999), although caution is needed until more complete investigations are carried out.

There are about 5600 clutches laid annually on monitored beaches in the other countries: about 3,000 in Greece; 600 in Cyprus (Margaritoulis et al., 2003a); and 2,000 or more in Turkey (Canbolat, 2004). The single most important nesting site known at present time, which has also the highest nest density, is Laganas Bay in Zakynthos (Margaritoulis, 2005). Thanks to long-term monitoring programmes, the following major nesting sites can be considered as index sites for monitoring trends of nesting activity: Zakynthos, Kiparissia Bay and Rethimno (Greece); Fethiye and Dalyan (Turkey); Lara/Toxeftra, Alagadi, and Chrysochou Bay (Cyprus).

Recent genetic studies have shown a population substructure within the Mediterranean (Schroth et al., 1996; Laurent et al., 1998; Carreras et al., 2007), due to the homing behaviour of females, which show a degree of fidelity to their natal site. A consequence is that loss of females in one site cannot be easily compensated by recruiting females from another one. As a result, each site should be treated as an independent Management Unit.

4.1.2. Marine habitats and migratory routes

In general, during their life loggerhead turtles first frequent open waters and feed upon pelagic prey; then they frequent shallow waters on the continental shelves and feed upon benthic prey (Bolten, 2003).

Significant numbers of juveniles are incidentally captured by pelagic longlines in the westernmost part of the Mediterranean - between the Strait of Gibraltar and Balearic Islands - and in the Sicilian Channel (Margaritoulis et al., 2003a) (Figure 4-1). Mediterranean loggerheads share these oceanic habitats with juvenile specimens of Atlantic origin (Laurent et al., 1998; Carreras et al., 2006b), most of which are probably dispersing males (Casale et al., 2002). However, their contribution to Mediterranean populations is still unclear. Stranding data indicates that the South Adriatic/North Ionian area is also an important oceanic habitat (Figure 4-1), most likely for juveniles originating from Greek nesting sites (Casale et al., 2005a). Large turtles in the neritic stage frequent the eastern basin, probably because this area has the most extensive shallow areas (on continental shelves) in the Mediterranean Figure 4-1). Incidental catch by bottom trawlers indicate that important numbers of large juveniles and adults frequent the shallow waters of the north Adriatic Sea, especially the eastern part (Lazar and Tvrtković, 1995; Casale et al., 2004), and on the continental shelf off Tunisia (Jribi et al., 2004; Casale et al., 2007a), as also indicated by adult females that were tagged while nesting in Greece and then re-encountered in these two areas (Margaritoulis et al., 2003a; Lazar et al., 2004a). High incidental catch from trawlers in southern Turkey (Oruç, 2001) and in Egypt (Laurent et al., 1996; Nada, 2001; Nada and Casale, 2008) also indicate important areas. Aerial surveys showed high turtle occurrence in the neritic habitats along the Spanish coast (Gomez de Segura et al., 2006). A recent model based on tag returns (Casale et al., 2007b) indicated heterogeneous behaviour and fidelity to both oceanic and neritic zones, and suggested movement patterns among oceanic areas, and from oceanic and neritic areas, such as from the Ionian/south Adriatic, to the north Adriatic and the Tunisian shelf.

There is still a lack of knowledge about migratory routes in the Mediterranean. From data gathered from tagging studies, adult females certainly have to migrate between Zakynthos (Greece), the north Adriatic and the continental shelf off Tunisia (Margaritoulis et al., 2003a), through the waters of the Ionian Sea and the Sicilian Channel. However, the presence in the eastern basin of important nesting grounds (Greece, Libya, Turkey, and Cyprus) and important neritic foraging grounds (on continental shelves in the Adriatic, and off Tunisia, Turkey, and Egypt) suggests a complex situation of adult migrations between these areas. For instance, genetic markers indicate that the Tunisian continental shelf is frequented by turtles originating at least form Greece, Turkey, Cyprus, and the Atlantic (Casale et al., 2008b), and migration of nesting females from Cyprus to this area has been observed through satellite tracking (Broderick et al., 2007). The Sicilian Channel connects the western and the eastern basins, and so it is likely to be an important migratory area. On the basis of incidental catch data, Camiñas and de la Serna (1995) suggested a seasonal migration pattern for juveniles in the western basin following major currents along the European and African coasts, and between the Atlantic and Mediterranean. Satellite tracking is giving further insights on migratory pathways (Bentivegna, 2002; Bradai et al., in press).

Hence, it is evident that loggerhead turtles move across many national boundaries during their lives.

4.2. *Chelonia mydas* (green turtle)

Chelonia mydas has a worldwide distribution, frequenting mainly tropical zones and oceanic and shallow waters. Information on this species in the Mediterranean has recently been reviewed by Kasparek et al. (2001). Genetic divergence indicates isolation from the Atlantic populations (Encalada et al., 1996), so that specific attention and conservation initiatives are required to safeguard the presence of this species in the Mediterranean.

4.2.1. Nesting sites

Nesting sites are restricted to the easternmost part of the basin (Figure 4-1; Table 4-1). Most nests are found in Turkey and Cyprus. The single most important site is Akyatan, Turkey (Kasparek et al., 2001). However, a recent survey showed that Syria also hosts a significant number of nests – possibly up to 100 (Rees et al., 2008). Some nests are also found in Lebanon. *Chelonia mydas* lays an average of over 1,000 clutches in the

Mediterranean annually (Broderick et al., 2002; Table 4-1).

4.2.2. Marine habitats and migratory routes

The most important foraging area of green turtles is in the easternmost part of the basin, between Turkey and Egypt (Laurent et al., 1996; Nada, 2001; Oruç, 2001). However, a foraging area for juveniles in southern Greece (Lakonikos Bay) has been discovered recently (Margaritoulis and Teneketzis, 2001) and there is evidence that Libyan waters are frequented by juveniles (Laurent et al., 1999). Although few juveniles are found in the Adriatic, Lazar et al. (2004b) suggest that the southern waters may host the developmental oceanic habitats. Occurrence in the western Mediterranean is unusual.

Satellite tracking of adult females nesting in northern Cyprus showed migratory routes in the waters between Cyprus, Turkey, Israel, and Egypt, and along the Egyptian and Libyan coasts (Godley et al., 2002). From this it is evident that green turtles move across national boundaries, especially those of the easternmost countries, while they inhabit the Mediterranean.

4.3. *Dermochelys coriacea* (leatherback turtle)

Dermochelys coriacea has a worldwide distribution, and although nesting is confined to tropical and sub-tropical zones, at sea this species has the widest latitudinal distribution among marine turtles. Information on this species in the Mediterranean has recently been reviewed (Casale et al., 2003a). The species occurs regularly in the Mediterranean (Caminas, 1998), although it is not known to currently nest in the region (Lescure et al., 1989; Laurent et al., 1999).The specimens found in the Mediterranean are most likely to be of Atlantic origin. Comparisons between pelagic longline catch rates in the Mediterranean (Casale et al., 2003a) and Atlantic (Watson et al., 2004) show that the Atlantic catch rate is 54 times higher, which suggests that the occurrence of this species in the Mediterranean is much lower than in the Atlantic.

This species has been noted in almost every area in the Mediterranean, but available data suggests that it mostly frequents specific areas such as the Tyrrhenian and Aegean Seas. The species is present all year round; there is no evidence of seasonality for longitudinal distribution and only possible seasonality for latitudinal distribution (Casale et al., 2003a). Only large juveniles and adults frequent the basin (Casale et al., 2003a); small juveniles are restricted to tropical waters (Eckert, 2002) so they probably do not occur as far north as the Strait of Gibraltar and therefore do not appear in the Mediterranean.

Table 4-1. Major nesting sites of *Chelonia mydas* and *Caretta caretta* in the Mediterranean. Libya is not included because comparable data is not available (see text). See Figure 4-1 for geographical distribution. *Caretta caretta* nests laid in these major nesting sites represent 84% of the total assessed in the Mediterranean - about 5,600 excluding Libya (see text).

Ref No.	Nesting Site	Average Annual No. of Nests		Source	Protection Status
		C. mydas	*C. caretta*		
Greece					
1	Zakynthos*		1301	Margaritoulis et al., 2003a	NMP, Nat2000(GR2210002)
2	Kyparissia Bay*		581	Margaritoulis et al., 2003a	Nat2000(GR2550005)
3	Lakonikos Bay		192	Margaritoulis et al., 2003a	Nat2000(GR2540003)
4	Bay of Chania		115	Margaritoulis et al., 2003a	Nat2000(GR4340003-GR4340006)
5	Rethymno*		387	Margaritoulis et al., 2003a	Nat2000(GR4330004)
Turkey					
6	Dalyan*		238	Canbolat, 2004	SPA
7	Dalaman		81	Canbolat, 2004	-
8	Fethiye*		109	Canbolat, 2004	SPA, ACS[1]
9	Patara		71	Canbolat, 2004	SPA, ACS[1]
10	Kale		109	Canbolat, 2004	-
11	Kumluca		227	Canbolat, 2004	-
12	Belek		560	Canbolat, 2004	SPA, NCS[1]
13	Kizilot		179	Canbolat, 2004	-
14	Demirtas		80	Canbolat, 2004	-
15	Anamur		176	Canbolat, 2004	NCS, ACS[1]
16	Goksu		100	Canbolat, 2004	SPA
17	Alata	128		Aymak et al., in press	
18	Kazanli	156		Canbolat, 2004	-
19	Akyatan	353		Canbolat, 2004	WCA[1]
20	Sugozu	213		Canbolat et al., in press	
21	Samandagi	84		Canbolat, 2004	-
Cyprus					
22	Lara/Toxeftra*	50	64	A. Demetropoulos and M. Hadjichristophorou, unpublished data, in WWF, 2005	MPA
23	Chrysochou Bay*		120	Margaritoulis et al., 2003a	Nat2000
24	Alagadi*	68	63	Kasparek et al., 2001; Broderick et al., 2002	SPA
25	North Karpaz	104		Kasparek et al., 2001	-
Syria					
26	Lattakia	104		Rees et al., 2008	-
Total		**1260**	**4753**		

ACS: Archaeological Conservation Site; MPA: Marine Protected Area; Nat2000: Natura 2000 site; NCS: Nature Conservation Site; NMP: National Marine Park; SPA: Specially Protected Area; WCA: Wildlife Conservation Area.
Source: [1]Canbolat (2004).
*Index sites (see § 4.1.1.1.)

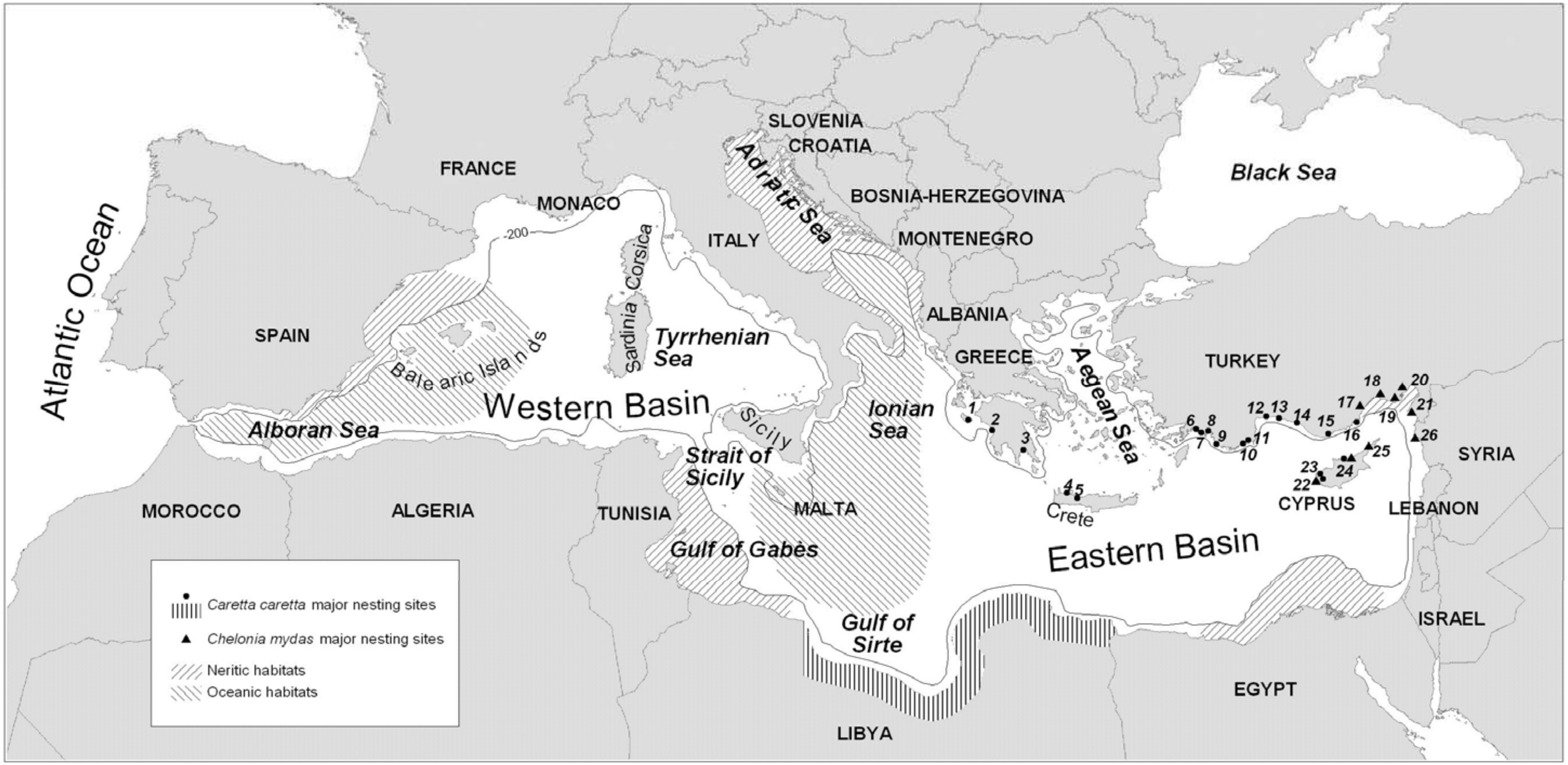

Figure 4-1. Main marine and nesting areas for *Chelonia mydas* and *Caretta caretta* in the Mediterranean. Modified from Margaritoulis et al. (2003a) with new information (see text). Numbers represent major nesting sites (see Table 4-1 and text for details and references): 1 Zakynthos; 2 Kyparissia Bay; 3 Lakonikos Bay; 4 Bay of Chania; 5 Rethymno; 6 Dalyan; 7 Dalaman; 8 Fethiye; 9 Patara; 10 Kale; 11 Kumluca; 12 Belek; 13 Kizilot; 14 Demirtas; 15 Anamur; 16 Goksu; 17 Alata; 18 Kazanli; 19 Akyatan; 20 Sugozu; 21 Samandagi; 22 Lara/Toxeftra; 23 Chrysochou Bay; 24 Alagadi; 25 North Karpaz; 26 Lattakia. The tract of Libyan coast with higher loggerhead nesting activity (Laurent et al., 1999) is also shown.

5. The legal framework for the protection of marine turtles in the Mediterranean

Marine turtles are considered to be protected species in most Mediterranean countries (Margaritoulis et al., 2003a).
International and supranational legislative tools to protect marine turtles in the Mediterranean have been reviewed by RAC/SPA (2003), which also provides guidelines to design new legislation. The legislation involving Mediterranean countries relevant for the conservation of marine turtles is briefly described below (official documents of the Conventions and RAC/SPA, 2003).
Legal instruments relevant for the conservation of marine turtles in the Mediterranean can be ascribed to two categories: those specifically addressing the protection of marine turtle species and those possibly involved in the management of fishing activities.

5.1. Protection of marine turtles

Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention)

- All Mediterranean countries and the European Union are parties.
- Article 1.
    1. For the purposes of this Convention, the Mediterranean Sea Area shall mean the maritime waters of the Mediterranean Sea proper, including its gulfs and seas, bounded to the west by the meridian passing through Cape Spartel lighthouse, at the entrance of the Straits of Gibraltar, and to the east by the southern limits of the Straits of the Dardanelles between Mehmetcik and Kumkale lighthouses.
    2. The application of the Convention may be extended to coastal areas as defined by each Contracting Party within its own territory.
    3. Any Protocol to this Convention may extend the geographical coverage to which that particular Protocol applies.

The Convention specifically aims at the protection of endangered wild fauna:

> Article 10: "The Contracting Parties shall, individually or jointly, take all appropriate measures to protect and preserve biological diversity, rare or fragile ecosystems, as well as species of wild fauna and flora which are rare, depleted, threatened or endangered and their habitats, in the area to which this Convention applies."

Furthermore:

> Article 4: "The Contracting Parties pledge themselves to take appropriate measures to implement the Mediterranean Action Plan […]"

> The *Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (MAP Phase II)* has among its objectives "to protect nature, and to protect and enhance sites and landscapes of ecological or cultural value" and indicates legal and management measures aimed to this goal, including the establishment of a list of "Specially Protected Areas of Mediterranean Importance" (SPAMI) and a list of endangered species.

One of the protocols to the Convention provides a detailed framework for protection of endangered species and their habitats:

> *Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean.* This protocol indicates species and habitats protection requirements that parties must incorporate into national legal frameworks. Obligations are particularly strong for species in the *List of Endangered or Threatened Species* (Annex II of the Protocol), which includes all marine turtle species occurring in the Mediterranean.

Convention on Biological Diversity (CBD)
All Mediterranean countries and the European Union are parties.
The Convention calls on parties to conserve biological diversity by several measures; e.g. by establishing a system of areas which are protected

or where special measures are taken, to manage biological resources, to promote the protection of ecosystems and the maintenance of viable populations of species, and to promote the recovery of threatened species.

Convention on the Conservation of Migratory Species of Wild Animals (CMS) – Bonn Convention
As of 1 August 2008: 17 Mediterranean countries and the European Union are parties of the Convention. Mediterranean countries which are not parties are: Bosnia-Herzegovina, Lebanon, Montenegro, Turkey.
All marine turtle species occurring in the Mediterranean are included in Appendix I of the Convention, which lists endangered migratory species.

Article 3, 4:

> Parties that are Range States of a migratory species listed in Appendix I shall endeavour:
> a) to conserve and, where feasible and appropriate, restore those habitats of the species which are of importance in removing the species from danger of extinction;
> b) to prevent, remove, compensate for or minimize, as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent the migration of the species; and
> c) to the extent feasible and appropriate, to prevent, reduce or control factors that are endangering or are likely to further endanger the species, including strictly controlling the introduction of, or controlling or eliminating, already introduced exotic species.

In 1999, the Conference of the Parties adopted a resolution (6.2) on by-catch species, including marine turtles, calling on parties to protect migratory species against by-catch in their territorial waters and exclusive economic zones, as well as by vessels with their flags fishing in the high seas.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
As of August 2008: 19 Mediterranean countries are parties of the Convention. Mediterranean countries which are not parties are: Bosnia-Herzegovina and Lebanon.

Under the Convention, parties must strictly regulate trade in species listed in its appendices and particularly Appendix I, where all marine turtle species occurring in the Mediterranean are listed.

African Convention on the Conservation of Nature and Natural Resources
All the five Mediterranean African countries (Morocco, Algeria, Tunisia, Libya, Egypt) are parties to the Convention.
All marine turtle species occurring in the Mediterranean are listed in Class A of the Convention.
Article 8, 1, a:

> Species in Class A shall be totally protected throughout the entire territory of the Contracting States; the hunting, killing, capture or collection of specimens shall be permitted only on the authorization in each case of the highest competent authority and only if required in the national interest or for scientific purposes.

Convention on the Conservation of European Wildlife and Natural Habitats – Bern Convention
As of August 2008: 14 Mediterranean countries and the EU are parties to the Convention. Mediterranean countries which are not parties are: Algeria, Bosnia-Herzegovina, Egypt, Israel, Lebanon, Libya, Syria.
All marine turtle species occurring in the Mediterranean are listed in Appendix II (strictly protected fauna species).

Article 4, 3:

> The Contracting Parties undertake to give special attention to the protection of areas that are of importance for the migratory species specified in Appendices II and III and which are appropriately situated in relation to migration routes, as wintering, staging, feeding, breeding or moulting areas.

Article 6:

> Each Contracting Party shall take appropriate and necessary legislative and administrative measures to ensure the special protection of the wild fauna species specified in Appendix II. The following will in particular be prohibited for these species:

a. all forms of deliberate capture and keeping and deliberate killing;
b. the deliberate damage to or destruction of breeding or resting sites;
c. the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation, insofar as disturbance would be significant in relation to the objectives of this Convention;
d. the deliberate destruction or taking of eggs from the wild or keeping these eggs even if empty;
e. the possession of and internal trade in these animals, alive or dead, including stuffed animals and any readily recognizable part or derivative thereof, where this would contribute to the effectiveness of the provisions of this article.

Habitats Directive
This is an instrument of the European Union to protect biodiversity.
At present, seven Mediterranean countries are members of the EU: Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain.
All marine turtle species occurring in the Mediterranean are listed in Annex IV (Animal and Plant species of Community interest in need of strict protection).
Article 12:

1. Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range, prohibiting:
   (a) all forms of deliberate capture or killing of specimens of these species in the wild;
   (b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration;
   (c) deliberate destruction or taking of eggs from the wild;
   (d) deterioration or destruction of breeding sites or resting places.

2. For these species, Member States shall prohibit the keeping, transport and sale or exchange, and offering for sale or exchange, of specimens taken from the wild, except for those taken legally before this Directive is implemented.
3. The prohibition referred to in paragraph 1 (a) and (b) and paragraph 2 shall apply to all stages of life of the animals to which this Article applies.
4. Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a). In the light of the information gathered, Member States shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned.

Furthermore, member states must designate sites (Natura 2000 network) hosting habitats of the species listed in Annex II. *Caretta caretta* and *Chelonia mydas* are listed as priority species in Annex II, because of their important nesting sites in member states (Greece and Cyprus).

5.2. Management of fisheries

United Nations Convention on the Law of the Sea (UNCLOS)
The UNCLOS is not specific for fisheries but is the legal framework for the rights of a country on marine resources. Territorial seas of Mediterranean countries, on average, extend for 12 nautical miles (nm) from their coastlines. Besides this, under UNCLOS, a coastal country may establish a further Exclusive Economic Zone (EEZ) up to 200 nm. In the relatively small Mediterranean basin (where countries are very close to each other) this would mean that an EEZ may be established up to the middle line between two countries. Within its EEZ, a country has to apply and enforce its legislation. This has very important implications for marine turtle conservation related to fisheries; for instance, an EU country should enforce the Habitats Directive within its EEZ.
However, no Mediterranean country has established EEZs, while some have extended unilaterally their rights on fishery resources only (Fisheries Protection Zones) through diverse legal formulas: Algeria (up to 32-52 nm), Spain (most of the Balearic Sea, a significant part of the Gulf of Lions, and adjacent areas), Libya, Malta, Syria, and Italy.

International Commission for the Conservation of Atlantic Tunas (ICCAT)
As of August 2008: 16 Mediterranean countries are members, either directly (Albania, Algeria, Croatia, Egypt, France, Libya, Morocco, Syria, Tunisia, Turkey) or through the EU (Cyprus, Greece, Italy, Malta, Slovenia, Spain).

The ICCAT is responsible for the conservation and management of tunas and tuna-like species (about 30 species) in the Atlantic Ocean and adjacent seas (like the Mediterranean). So it concerns only fisheries (e.g. drifting longline) that target these species. Non-target species (sharks) and incidental captures (turtles) are also included in the statistics. It has the power of adopting resolutions that are binding for member countries.
The ICCAT is responsible for tuna and swordfish fisheries in the Mediterranean and can adopt measures for turtle conservation (e.g. fishing in closed areas, reduction of effort, change of gear, etc.)

General Fisheries Commission for the Mediterranean Sea (GFCM)
All Mediterranean countries are members. The GFCM has the power to establish management measures on fishery activity, which must be adopted by all vessels flying the flags of member countries. It has also adopted measures to ensure than non-member vessels do not undermine management and conservation in the Mediterranean. GFCM also adopt ICCAT resolutions for the protection of the resources and non-target species.

European Union
At present, seven Mediterranean countries are members of the EU: Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain.
Mainly through its Common Fisheries Policy, the EU has competence for fisheries management and conservation in the waters of its members [Common Fisheries Policy (EC 2371/2002) with the new Action Plan for Mediterranean (COM 2002 535 final) and the Action Plan for integration of environmental aspects in fishing].

6. The Mediterranean fishing fleet

Fleet statistics for most Mediterranean countries are shown in Table 6-1. Data are from heterogeneous sources and there are several gaps on fishing gear within a country or on whole countries. Different countries have different criteria for classify vessels into fishing gear. For instance, often only large vessels are included while the others are considered "small" or "artisanal" vessels or may be not registered at all. In some cases, the different fishing gear considered in this report are pooled together in larger classes in fleet statistics.

For these reasons, these fleet data should be taken with caution, both because they have a certain degree of uncertainty and also because they often represent an underestimation of the real fleet.

Fig. 6-1. Artisanal vessels at El Max, Egypt (P. Casale)

Table 6-1. Fishing fleet of Mediterranean countries by fishing gear: Bottom Trawl (BT); Pelagic Longline (PLL); Demersal Longline (DLL); Set Net (SN). In some cases number of vessels refer to more than one gear. Subtotal: sum of values of each fishing gear; Total: total number of vessels as directly provided by fishery statistics; Total/Subtotal: total number of vessels, if Total was not available, Subtotal was used. Source and Notes: 1) Eurofish Magazine 1, 2005; 2) Copemed, www.faocopemed.org; SN: trammel nets; 3) Jahutka and Misura, 2005. SN: only northern part, Lazar et al., 2006. 4) EU Fleet Register; 5) General Authority for Fisheries Resources Development, Egypt. 6) EU Fleet Register; Mediterranean ports only. 7) Shapiro, 2006. 8) Copemed, www.faocopemed.org; BT: FAO Fishery Country Profile. 9) Copemed, www.faocopemed.org; Mediterranean ports only. 10) Anonyme, 2006. 11) Prime Ministry Republic of Turkey, Turkish Statistical Institute, Fishery Statistics 2006. Aegean + "Mediterranean": Black Sea not included.
*This figure appears in demersal longline statistics but it probably refers to all longlines.

Country	**BT**	**PLL**	**DLL**	**SN**	**Subtotal**	**Total**	**Total/Subtotal**	**Year**	**Source and notes**
Albania	148	-	-	49	197	201	201	2003	1
Algeria	-	105	175	1,754	2,034	-	2,034	2000	2
Bosnia and Herzegovina	-	-	-	-	-	-	-		
Croatia	518	80		234-1,437	2,035	3,684	3,684	2001, 2005	3
Cyprus	15	31	-	825	871	868	868	2006	4
Egypt	1,150	-	1,120	374	2,644	3,027	3,027	2004	5
France	38	88	245	1,312	1,683	1,929	1,929	2006	6
Greece	364	546	12,127	5,387	18,424	17,781	17,781	2006	4
Israel	32	-	-	-	32	-	32	2005	7
Italy	3,415	-	5,289*	2,675	11,379	13,960	13,960	2006	4
Lebanon	-	-	-	-	-	-	-		
Libya	123	42	6,689	5,624	12,478	-	12,478	2000	8
Malta	15	109	572	369	1,065	1,405	1,405	2006	4
Monaco	-	-	-	-	-	-	-		
Montenegro	-	-	-	-	-	-	-		
Morocco	-	6,731		3,530	10,261	-	10,261	2000	9
Slovenia	19	-	-	140	159	165	165	2006	4
Spain	1,080	107	135	2,364	3,686	4,009	4,009	2006	6
Syria	-	-	-	-	-	-	-		
Tunisia	400	-	10,501		10,901	-	10,901	2005	10
Turkey	360	7,414			7,774	8,146	8,146	2005	11
Total							**90,881**		

7. Interaction with fisheries in the Mediterranean

7.1. Objectives and limits

This chapter aims to provide an estimate of the number of turtles caught and killed by the main types of fishing gear in the Mediterranean (bottom trawl, pelagic and demersal longline, set net).
It is worth to mention that driftnets were first banned by the EU and since their use was banned by ICCAT and GFCM the ban now covers the whole of the Mediterranean.
Due to the many parameters involved (see § 3.) and the great variability in fishing gear and activity among and within Mediterranean countries, a reliable estimate would ideally require on-board investigation of a high proportion of the fleet for each gear in every port of the whole Mediterranean. Since this is unlikely to be feasible, the aim here is to provide the best estimate possible with the limited available information, adopting a conservative approach, i.e. in case of gaps or multiple information, catch or mortality estimates are kept to the lowest values, so to avoid overestimation. For the intrinsic limitations, these estimations can give insights on the magnitude of the turtle bycatch problem, but should not be regarded as reliable exact figures.

7.2. Methods

Available information on turtle bycatch in the Mediterranean was reviewed and relevant data (catch rates and mortality) were summarized according to fishing gear and country/area (Tables. 7-1, 7-2, 7-3). In some cases, these data were not available as such in the original papers and so were calculated from other data.
In order to estimate the total number of captures, the Mediterranean was divided in contiguous countries (Tables 7-4, 7-5, 7-6, 7-7). Whenever available, fleet and turtle catch rate data were compiled for each country. In case of multiple data for the same country, the most recent or accurate data were selected. When the unit of catch rate (e.g. vessel-day, vessel-month) was not the same of the unit of fishing effort (typically the vessel), conversion factors (known or plausible) were used to convert catch rates to the relevant unit of fishing effort. As an indirect approach, countries without catch rates were assigned catch rates from the next country, unless distance or fishing parameters of different fisheries were suspected to make a difference (see examples in Tables 7-4, 7-5, 7-6, 7-7). In this case, a very low catch rate was used as a minimum value (conservative approach).
For each country, the total number of captures per year was calculated from catch rates and fishing efforts. In case of range of values, minimum and maximum values were both reported.

7.3. Bottom trawl

The most relevant data about turtle interaction with bottom trawlers in the Mediterranean are provided in Table 7-1.

7.3.1. Number of captures

Available direct estimates indicate high numbers of captures by fleets from Italy, Tunisia, Croatia, Turkey and Egypt, and lower though important numbers for Greece, Spain and Algeria (Table 7-1). The indirect approach (§ 7.2) for estimating captures in most of the Mediterranean areas suggests high numbers for Greece, Libya, and also Albania (Table 7-4).
As a whole, Italy and Tunisia appear to be by far the countries with the most important numbers, with potentially over 20,000 captures per year altogether. Other five countries may well capture more than 2000 turtles per year each: Croatia, Greece, Turkey, Egypt, and Libya. Finally, Spain and Albania may capture a few hundreds per year each.
For other countries, captures could not be estimated even with indirect approaches, due to lack of information on fishing effort. Three of these countries (Monaco, Bosnia and Herzegovina, and Montenegro) have limited coastline and probably their fishing fleet and associated turtle bycatch is relatively small. On the other hand, Syria and Lebanon may have a relevant impact, which could be particularly important for the small green turtle population occurring in that area (Fig. 4-1). Morocco and Algeria fleets may also capture many (loggerhead) turtles per year. Although an estimation is available in literature for Algeria (Table 4-1), it is very old and parameters, including the fishing fleet, may have changed dramatically since then.
From what above, the most affected marine areas are the north African continental shelves (Tunisia, Libya, Egypt), the Adriatic, the Levantine basin, and the Aegean.

For the conservative approach used in these estimations and for the information gaps in several countries, available data suggest that the annual number of captures by Mediterranean trawlers may well be above 40,000 (Table 7-1).
It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time.

7.3.2. Number of deaths
Trawl induced mortality depends on variable factors (e.g. tow duration; see § 3.1.2.1.) that can make mortality varying greatly among and within country fisheries. Available RMR from samples of minimum 27 turtles range from 0.6% to 12.5% while comatose turtles ranged 0-34% (Table 7-1). On these bases a conservative approach could be to assume 5% (lower than the median of the above range) as an average RMR and 15% (lower than the median of the above range) as an average comatose turtle proportion. Assuming that comatose turtles die if released in that condition, overall average mortality is assumed as 20%, resulting in at least 7400 turtles killed per year by bottom trawlers in the Mediterranean, but probably over 10,000 (Table 7-8).

7.3.3. Affected part of the population and species
Turtle caught by bottom trawlers are necessarily those frequenting the sea bottom, and so they include large juveniles and adults. Accordingly, available information on turtle size indicate medium-large individuals on the average (mean: 53.9 cm CCL; range: 22-87; n=648; Table 7-1). However, in some areas trawlers catch turtles in the lower part of the size range too: turtles as small as 22 cm and 29.5 cm CCL were caught in the north African and Adriatic shelves respectively (Table 7-1: Italy, central Med and Adriatic) and benthic feeding was observed in a wide size range in the central Mediterranean (Casale et al., in press b). This suggests that in the Mediterranean bottom trawlers interact with a large portion of the population, including not only large individuals (with the highest reproductive value) but also part of the small juveniles. Therefore, depending on the mortality rate induced (still poorly known, see above), this fishing gear might have a tremendous impact on Mediterranean populations. Depending on the occurrence of Atlantic individuals on neritic areas (§ 4.1.2.), also their populations can be affected.
All the identified countries/areas concern loggerhead turtles, while green turtles are captured basically in the Levantine basin, according to their distribution (§ 4.2.2.), with most captures in Egypt and Turkey.

7.4. Pelagic longline
The most relevant data about turtle interaction with pelagic longliners in the Mediterranean are provided in Table 7-2.

7.4.1. Number of captures
Available direct estimates indicate high numbers of captures by fleets from Greece, Italy, Morocco, Spain, Tunisia (Table 7-2). The indirect approach for estimating captures in most of the Mediterranean areas suggests high numbers in Malta and Libya too (Table 7-5).
The country with the highest number of captures is probably Spain, followed by Morocco and Italy, each one with 10,000 captures per year or more (Table 7-5). Four other countries, Greece, Malta, Libya, and Tunisia, probably have 1000-3000 captures per year each.
For other countries, captures could not be estimated even with indirect approaches, due to lack of information on fishing effort. Four of these countries (Monaco, Slovenia, Bosnia and Herzegovina, and Montenegro) have limited coastline and probably their fishing fleet and associated turtle bycatch is relatively small. On the other hand, other seven countries (Croatia, Albania, Turkey, Cyprus, Syria, Lebanon, Israel, and Egypt) may have a relevant impact. For Egypt, official data do not distinguish between pelagic and demersal longlines. Given the artisanal characteristic of the fleet, those vessels have been here ascribed to demersal longline (Table 7-6), but probably part of them are actually pelagic longliners.
From what above, the most affected marine areas are the Alboran/Balearic area, the Strait of Sicily, and the Ionian.
For the conservative approach used in these estimations and for the information gaps in several countries, available data suggest that the annual number of captures by Mediterranean pelagic longliners may well be above 50,000 (Table 7-5).
It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time.

7.4.2. Number of deaths
Mortality induced by pelagic longline is basically due to the lesions caused by the ingested hooks and branchlines (see § 3.2.2.2., 3.2.2.3., 3.2.2.4.). For this reason, differently from trawl and from other gear causing immediate death by drowning,

the observed RMR of pelagic longline is relatively low (0-4%; Tab. 7-2). PMR is not known with certainty, but available data suggest that it is higher than 30% (Casale et al., 2008a). On these bases a conservative approach could be to consider the average mortality induced by pelagic longlines in the Mediterranean as 40%, resulting in at least 20,000 turtles killed per year (Table 7-8).

7.4.3. Affected part of the population and species

Average size of turtles caught by pelagic longline (48.9 cm CCL; range: 20.5-79.2; n=1868; Table 7-2) is smaller than those caught by trawlers (53.9 cm; see above). This is probably due to the oceanic zone where pelagic longliners fish, which is theoretically frequented by smaller turtles. However, the difference is small and the size ranges largely overlap, indicating that pelagic longliners may capture turtles of all sizes and in all ecological stages, as indicated also by recent dietary data (Casale et al., in press b).

All the identified countries/areas concern loggerhead turtles, while just few green turtles are reported among captures by pelagic longlines, probably due to their herbivore diet and the different areas they frequent.

7.5. Demersal longline

The most relevant data about turtle interaction with demersal longliners in the Mediterranean are provided in Table 7-2.

7.5.1. Number of captures

Available direct estimates indicate high numbers of captures by Tunisian and Egyptian vessels (Table 7-2). The indirect approach for estimating captures in most of the Mediterranean areas suggests high numbers in Libya, Greece, Turkey, Morocco, and also in the wider Italy (Table 7-6).

The countries with the highest number of captures (thousands per year) are probably Tunisia, Libya, Greece, Turkey, Egypt, Morocco, and Italy. For Italy, Greece, Algeria and Morocco a conservative catch rate of one turtle every two years was applied, and should the real catch rate be higher, these would have much higher number of captures, especially Italy, Greece, and Morocco.

For other countries, captures could not be estimated even with indirect approaches, due to lack of information on fishing effort. Four of these countries (Monaco, Slovenia, Bosnia and Herzegovina, and Montenegro) have limited coastline and probably their fishing fleet and associated turtle bycatch is relatively small. On the other hand, other six countries (Croatia, Albania, Cyprus, Syria, Lebanon, and Israel) may have a relevant impact. For Egypt, official data do not distinguish between pelagic and demersal longlines. Given the artisanal characteristic of the fleet, those vessels have been here ascribed to demersal longline, but given that official statistics are probably underestimated, the fleet considered here is unlikely to be higher than real.

From what above, the most affected marine areas are the north African continental shelf (Tunisia, Libya, Egypt), the Alboran Sea (Morocco), the Levantine basin, and the Aegean.

For the conservative approach used in these estimations and for the information gaps in several countries, available data suggest that the annual number of captures by Mediterranean demersal longliners may well be above 35,000 (Table 7-6).

It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time.

7.5.2. Number of deaths

Mortality induced by demersal longline is due to at least two types of factors. First, turtles may drawn because impeded to go to the surface to breathe by this gear anchored to the sea bottom. Accordingly, available RMR of demersal longline (13%) is higher than that of pelagic longline (Table 7-2). Second, turtles may die for the lesions caused by the ingested hooks and branchlines, like pelagic longline (see § 3.2.2.2., 3.2.2.3., 3.2.2.4.). Demersal longliners typically use smaller hooks than pelagic longliners, so that post-release mortality induced by hooks might be lower; however, branchlines alone probably cause a high mortality in turtles captured by pelagic longline (Casale et al., 2008a) and it is reasonable that it is the same for those caught by demersal longline. The combined dead and comatose turtles (indication of potential mortality) observed in Tunisia was 33% (Table 7-2). On these bases, at the present state of knowledge a conservative approach would be to consider mortality induced by demersal longline at least equal to pelagic longline (40%; see § 7.4.2.), resulting in at least 14,000 turtles/year killed in the Mediterranean (Table 7-8).

7.5.3. Affected part of the population and species

Average size of turtles caught by demersal longline (51.8 cm CCL; n=35; Table 7-2) is slightly larger than those caught by pelagic longline (see § 7.4.3.). This is probably due to the

neritic zone where demersal longliners fish, which is theoretically frequented by larger turtles. However, area coverage and sample size are small, so this value might not be representative on a regional scale.
All the identified countries/areas concern loggerhead turtles. Studies on interaction of demersal longline with turtles are very few and in places where green turtles are not abundant, but it is plausible that they can be caught by demersal longlines in the Levantine basin.

7.6. Set net

The most relevant data about turtle interaction with set nets in the Mediterranean are provided in Table 7-3.

7.6.1. Number of captures

An indirect approach based on tag returns, suggested that in the Mediterranean set nets may capture as many turtles as other fishing gear like trawl (Casale et al., 2005b).
Available direct estimates indicate high numbers of captures in Croatia, Egypt and Tunisia. There are indications of high interaction in Turkey and Cyprus too, although they refer to both longlines and set nets (Table 7-3). The indirect approach for estimating captures in most of the Mediterranean areas suggests high numbers also in France, Italy, Greece, Libya, and Morocco (Table 7-7).
The countries with the highest number of captures (thousands per year) are probably Tunisia, Libya, Greece, Turkey, Cyprus, and Croatia. Italy, Morocco, Egypt, and France are probably important too. For Italy, Greece, and Morocco a conservative catch rate of one turtle every two years was applied, and should the real catch rate be higher, these would have much higher number of captures.
For other countries, captures could not be estimated even with indirect approaches, due to lack of information on fishing effort. Three of these countries (Monaco, Bosnia and Herzegovina, and Montenegro) have limited coastline and probably their fishing fleet and associated turtle bycatch is relatively small. On the other hand, other four countries (Albania, Syria, Lebanon, and Israel) may have a relevant impact.
From what above, the most affected marine areas are the north African continental shelf (Tunisia, Libya, Egypt), the Levantine basin, the Aegean, and the Adriatic.
For the conservative approach used in these estimations and for the information gaps in several countries, available data suggest that the annual number of captures by Mediterranean set nets may well be above 30,000 (Table 7-7).
It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time.

7.6.2. Number of deaths

Mortality induced by set net is basically due to forced apnea, because set nets are left for many hours or even days at sea and the turtle cannot easily come to the surface to breathe, especially for nets set at deep bottoms. Combining all the available data (Table 7-3) the average RMR is 51.8% (n=438; Table 7-3), and even higher (82.6%; n=69) from the three records concerning set nets targeting lobsters (Table 7-3), which are usually set deeper. Furthermore, turtles can suffer PMR too, if released with pieces of the net attached to the body. On this bases, at the present state of knowledge a conservative approach would be to consider mortality induced by set nets as 60%, resulting in at least 16,000 turtles killed per year (Table 7-8).

7.6.3. Affected part of the population and species

Average size of turtles caught by set nets (45.4 cm CCL; n=74; Table 7-3) is slightly smaller than other gear and suggest that in spite set nets fish in shallow waters typically frequented by large turtles, small juveniles can be caught too. However, area coverage and sample size are small, so this value might not be representative.
All the identified countries/areas concern loggerhead turtles. Studies on interaction of set net with turtles are very few (Table 7-3), but it is likely that they can are caught by set net in the Levantine basin.

7.7. Intentional killing

In most cases intentional killing was not clearly addressed, it was anecdotic, and in some cases the information is old. Nonetheless, it seems that, although at various degrees, intentional killing occurred and probably still occurs in several Mediterranean countries, such as Algeria, Egypt, France, Greece, Morocco, Tunisia, Turkey, Cyprus, Syria (Tables 7-1, 7-2, 7-3).
In most cases intentional killing is driven by the use of meat or carapace. In France, Laurent (1991) reported that most turtles were released but some were sold to aquaria or restaurants, and intentional killing in Corsica was mentioned by Delaugerre (1987), although it is not clear how common it was, also because most turtles were already dead at gear retrieval. In Algeria, Laurent (1990)

reported that most fishermen released the turtles while some used to kill turtles for the carapaces (house decoration, guitars etc.), for the oil (thought to have therapeutic properties), or for the meat. In Morocco, Laurent (1990) reported that most fishermen released the turtles caught while some used to kill them for selling the carapaces to tourist shops and for the meat, and tourist shops were still selling carapaces in 2003 (Benhardouze et al., 2004). In Tunisia, in 1995 turtles were sold in black markets only (Laurent et al., 1996) in contrast to previous times when turtles were sold in fish markets too (Laurent et al., 1990; Laurent and Lescure, 1994), and turtles can be consumed directly onboard (Bradai, pers. comm., in Margaritoulis et al., 2003a). In Turkey, fishermen usually released the turtles but sometimes killed them for blood or meat (Laurent et al., 1996). In Cyprus, part of the fishermen killed turtles for personal use: carapace, meat, as well as blood and fat (thought to have therapeutic properties) (Godley et al., 1998). In Egypt, most fishermen of the Alexandria port and some fishermen of other areas kill and consume turtles onboard or bring meat on land, for personal use or trade in the black market (Nada and Casale, 2008); till recent years turtles were openly sold in the Alexandria fish market (Laurent et al., 1996). In Syria turtles are killed for consumption of meat and blood (Jony and Rees, in press) but also for other reasons (see below). Turtle are consumed onboard by some foreign crews in Greece (Panou et al., 1992) and Italy (Gerosa and Casale, 1999).
In other cases intentional killing is driven by antagonism and competition for fish. In Greece, 23% of stranded turtles show evidence of intentional injuries (Kopsida et al., 2002), and 41.6% of turtles brought to the national sea turtle rescue center have injuries caused intentionally (n=469, 1994-2005), while interviews reveal that 30% of fishermen are openly hostile towards turtles and 50% justify who kill turtles (Panagopoulou et al., 2007). In Syria, many fishermen stated that they kill turtles whenever in their nets and some fishermen use to release them injured and bleeding as this is believed to induce the other turtles to leave the area (Jony and Rees, in press).Longline fishermen sometimes kill turtles to recover expensive hooks (e.g. Italy; Casale and Cannavò, 2003).

7.8. Ghost fishing

"Ghost fishing" refers to fishing gear lost and so no longer controlled by fishermen that continue to fish. Probably turtles can be captured both by ghost longlines and set nets. Regarding longlines, turtles can be captured by hooks as long as the baits are in place, then the hooks become no longer attractive but turtles can still get entangled in the main line and branchlines, also because both turtles and drifting ghost longline may converge to the same areas. In this case, fishing gear can also be considered as marine debris. Ghost set nets capture fish for months, thought with a decreasing capacity (e.g. Erzini et al., 1997). However, these dead fish may be an attraction for turtles, so increasing the probability of capture. Unfortunately, little is known on ghost gear. The amount of gear lost every year in the Mediterranean is unknown, and there are no data about interaction with turtles. However, given the high longline and set net fishing effort in the region, gear loss is probably high, and it is likely that turtle capture by ghost gear represents an important cause of additional mortality.

7.9. Overview

Estimating catches has an intrinsically source of uncertainty, so that all results should be considered for the overall conclusions rather than for the specific figures.
Results indicate that turtle bycatch consists in more than 150,000 captures per year with possibly over 50,000 deaths (Table 7-8), and although impressive this is probably an underestimation. First, official fleet statistics do not include all the existent vessels, especially the small boats using artisanal gear such as set nets, demersal longline, and in many cases also pelagic longlines. Second, fleet statistics from many countries were not available at all for this analysis (Table 6-1). Third, catch rates were not available for all countries and fishing gear and very conservative values were tentatively applied instead (e.g. one turtle every two years). Fourth, any use of catch rates from different countries, any conversion between different units of catch rates, and any assignment of vessels to a specific fishing gear followed a conservative approach (Tables 7-4, 7-5, 7-6, 7-7). All this considered, annual captures in the Mediterranean may well be much higher, like 200,000 or even more. It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time.
Although with the uncertainty mentioned above, small/artisanal vessels using set nets, demersal longline and a good part of pelagic longline, are apparently responsible for more captures than large/industrial vessel, typically trawlers and just a part of longliners (Table 7-8), especially

considering that the gaps in official statistics typically concern small boats.
The impact of artisanal gear is even more evident if mortality is considered (Table 7-8) since mortality rate of artisanal gear is probably higher than trawlers, so that overall number of deaths caused by artisanal gear is probably much higher than that caused by trawlers.
Another interesting finding is that deaths caused by set nets and demersal longline may be as important as those induced by bottom trawl and pelagic longline, the two fishing gear on which attention for sea turtle conservation has been focused so far.
As far as intentional killing is concerned, artisanal fishermen are those more involved both in meat consumption and in antagonism (§ 7.7.).
As far as ghost fishing is concerned, bottom trawlers are not a source of this kind of problem, because they do not loose the net and even if so, the net must be towed to capture turtles, while ghost fishing is typical of "passive" gear such as set nets.
In conclusion, in the Mediterranean small/artisanal vessels using set nets, demersal longlines and pelagic longlines appear to be very important, at least as large/industrial vessels (especially trawlers) or even more than them, for all the aspects contributing to the impact on sea turtle populations (number of captures, mortality rate, intentional killing, ghost fishing).

Table 7-1. Review of data about turtle capture by trawlers in the Mediterranean. Countries are listed in alphabetical order.

Gear	Target species	Country fleet	Area	Turtle Species	Captures/yr	CI 95%		Mortality Rate (%)			Deaths/yr		Intentional killing	Turtles/ year-boat	Turtles/ month-boat	Turtles/day-boat	Turtles/ tow	Turtles/ tow-hr	Std Catch Rate	N turtles	Turtle CCL (cm) Avg (range; n)	Mean tow duration (min)	Depth (m)	Boat lenght (m)	Study period	Method	Source
								Dead	Comatose	Potential	Dead	Potential															
BT		Algeria		Cc	284								some	1.41									0-100		1989	I	11
BT				Cc	2500									2-10							40-100		<200		winter	I	13
		Croatia																				367					20
BT				Cc				12.5												32			<200		1992-2002		14
BT		Egypt		Cc, Cm, Dc	thousands			0-10					all	1-20							Cc: 64.7 (49.4-83;16) Cm: 91 (1)				Mar 1995	I	10
BT		Egypt		Cc, Cm	2269								many	1.72											2007	I	17
BT		France	Corsica	Cc				3.7												27					1985	I	6
BT			mainland	Cc	<100			3.3					some	0-3						92			20-80		Jun-Sep 1990	I	12
BT			Lakonikos Bay	Cc				2.6					yes							38		60-180	36-270			L	15
BS			Lakonikos Bay	Cc																						L	15
BT	F	Greece	Thracian Sea	Cc	410	0	976	0								0.0625				2	42.5 (34.5-48; 3)				1999, spring/autumn	O	16
BT	F		Thracian Sea	Cc	298	37	559									0.01851			0.00631	1		202			2000 autumn	O	16
BT	F		Ionian Sea	Cm	211	0	626	0												1	45 (1)				2000 spring	O	16
BT	F, CE, CR		Adriatic NW	Cc	4273	2186	8546	9.4	34.4	43.8	402	1,872				0.052			0.0037	32	54.2 (29.5-82; 61)	160	7.1-134		1999-2000	O, L	4
BT	F, CE		Adriatic NE	Cc	many			0.6	0	0.6						0.701			0.0548	122		78	7.1-134		1999-2000	O, L	4
MT	F	Italy	Adriatic NW	Cc	161			7.7	30.8	38.5	12	62				0.0159				13		65	5.2-89.5		1999-2000	O, L	4
BT			Adriatic NW													0.4384				64		198			1999-2001	L	19
BT	F, CE, CR		Central Med	Cc	4056	2924	5187							38-161		0.332-1.121			0.027-0.089	672	51.8 (22-87; 368)	50-225	<200	11-31	2003-2005	L, PS	5
BT		Spain	Balearic islands	Cc	13	5	21	50			6				0.018					13					May-Aug 2002	I	3
BT			North		270	134	406								0.07											O, I	1
BT	S, F, CE			Cc				0					many			0.714	0.077	0.023		15	73.4 (15)	197	29-42		Jan-Mar 1990	O, L	8
BT				Cc																40	61.6 (40)				Jan 1989	PS	8
BT	F, S	Tunisia		Cc									many								53.7 (25)				Jan 1995	PS, MS	10
BT	S			Cc	2000-2500																51.3 (61)				Jun-Jul 1991	O, other	2
BT				Cc, Cm	>2000								many												Jun-Aug 1988	I	9
BT	S, CE, F			Cc	5458	3806	7110	3.33	1.67	5	182	273				0.121	0.011	0.008	0.00645	60	57.5 (36.5-84.5; 57)	86.8	7-64		2001-2002	O	7
BT				Cc	many			0								0.25				1	61 (1)	117-163	70-130		Jan-Feb 1995	O	10
BT				Cc, Cm, Dc	many								some	4-500								180			Jan-Feb 1995	I	10
BT				Cm										8.5		0.0500				34	61%: 30-60 (82)		0-100		Sep 1996 - May 1997	O, L	18
MT		Turkey	Levantine Basin	Cm				0.4	8.6	9				33.4		0.1963				267			0-50	18-28	Sep 1996 - May 1997	O, L	18
BT				Cc										11.0		0.0647				44	82%: 30-60 (190)		0-100		Sep 1996 - May 1997	O, L	18
MT				Cc				0	12.7	12.7				9.0		0.0529				72			0-50	18-28	Sep 1996 - May 1997	O, L	18
BT/MT				Cm				0.0063	0					32.0						160					Oct 1995 - Jul 1996	O, L	18
BT/MT				Cc				0	0.0769					5.2						26					Oct 1995 - Jul 1996	O, L	18

Gear, BT: Bottom Trawl; MT; Midwater Trawl; BS: Beach Seine

Target Species, F: Fish; CE: Cephalopods; CR: Crustaceans; S: Shrimps

Method, I: Interview; O: Onboard observation; L: Logbook; PS: Port survey; MS: Market Survey.

Turtle species, Cc: *Caretta caretta*; Cm: *Chelonia mydas*; Dc: *Dermochelys coriacea*

Mortality rate and Deaths, Potential: includes both Dead and Comatose

Std Catch Rate: turtles per tow/30.5 m headrope length*60 min; §3.1.1.1.

Vertical bars indicate that values on the right refer to multiple raws

Source: 1: Alvarez de Quevedo et al., 2006; 2: Bradai, 1992; 3: Carreras et al., 2004; 4: Casale et al., 2004; 5: Casale et al., 2007a; 6: Delaugerre, 1987; 7: Jribi et al., 2007; 8: Laurent and Lescure, 1994; 9: Laurent et al., 1990; 10: Laurent et al., 1996; 11: Laurent, 1990; 12: Laurent, 1991; 13: Lazar and Tvrtkovic, 1995; 14: Lazar et al., 2003; 15: Margaritoulis et al., 1992; 16: Margaritoulis et al., 2003b; 17: Nada and Casale, 2008; 18: Oruç et al., 1997, Oruç, 2001; 19: Vallini et al., 2003 ; Lazar et al., 2007.

Table 7-2. Review of data about turtle capture by longliners in the Mediterranean. Countries are listed in alphabetical order.

Gear	Target species	Country fleet	Area	Turtle Species	Captures/yr	CI 95%		Dead (%) at retrieval	Deaths/yr	Intentional killing	Turtles/year-boat	Turtles/day-boat	Turtles/month-boat	Turtles/1000 hooks	N turtles	Turtle CCL (cm) Avg (range; n)	Boat lenght (m)	Hook type and size (cm)	Bait	Lightsticks	Study period	Method	Source
PLL	SWO	Algeria			284						2.8											I	14
DLL		Egypt		Cc, Cm	2218					many	1.9										2007	I	16
PLL	SWO	Greece	E Ionian/Aegean	Cc	3310			4.3				0.086		0.172	22	56.3 (37-74.8; 22)	7-18.1			Yes	1999-2000	O	13
PLL	SWO	Greece	E Ionian/Aegean	Dc	171							0.004		0.008	1	132.2 (1)	7-18.2			Yes	1999-2000	O	13
PLL	SWO	Greece	E Ionian	Cc	280						7.7	0.199			156			7-8	M, P		1989-1995	L	18
PLL	SWO	Greece	E Ionian	Cm								0.001			1			7-8	M, P		1989-1995	L	18
PLL	SW	Italy	Central Med	Cc	2148	1659	2645				27.2	1.071		0.977	91	45.9 (28-79; 75)	8-11.2	J, 8.1	M, P		Jun-Sep 2005	L	8
DLL	DF	Italy	Lampedusa isl.	Cc	257	94	421					0.786		0.873	11	58.6 (27.1-72; 11)	7.4-11.5	J, 3.1-4.8	SQ		Jun-Sep 2006	L	8
PLL		Italy	Central Med	Cc										0.88									15
PLL	SW	Italy	N Ionian	Cc, Cm	156 (c)			0				0.207		0.128	30	43.8 (115)		J, 8-9	M		1999-2000	O	10
PLL	SW	Italy	S Ionian	Cc, Cm	1497 (c)			0				0.535		0.446	85			J, 5-7	P, SQ, M		1999-2000	O	10
PLL	ALB	Italy	N Ionian	Cc, Cm	326 (c)			0				0.803		0.317	57	37.2 (83)		J, 3	P		1999-2000	O	10
PLL	ALB	Italy	S Ionian	Cc, Cm	1074 (c)			0				0.560		0.195	28			J, 2-4	P		1999-2000	O	10
PLL	SWO	Italy	S Thyrrhenian	Dc								0.042		0.051	1			J, Mustad #0-5	M, SQ, P		1998-1999	O	11
PLL	SWO	Italy	S Med (a)	Dc								0.018		0.018	2			J, Mustad #0-5	M, SQ, P		1998-1999	O	11
PLL	SWO	Italy	S Thyrrhenian	Cc								0.167		0.204	4			J, Mustad #0-5	M, SQ, P		1998-1999	O	11
PLL	SWO	Italy	S Med (a)	Cc	47000-68000							0.132		0.136	15			J, Mustad #0-5	M, SQ, P		1998-1999	O	11
PLL	ALB	Italy	Central Med	Cc				12 (b)				9.000		3.090	54			J, Mustad #6-7	P		1998-1999	O	11
PLL	ALB	Italy	S Adriatic	Cc								0.429		0.200	3			J, Mustad #6-7	P		1998-1999	O	11
PLL	BFT	Italy	Central Med	Cc								0.750		2.140	6			"Japan" #4.5-4.8	M, SQ		1998-1999	O	11
PLL	ALB	Italy	N Ionian	Cc, Dc								0.350		0.203	477			3	P		1978-1979	L	9
PLL	SWO	Italy	N Ionian	Cc, Dc								0.067		0.075	71			10	M		1978-1979	L	9
PLL	SWO	Italy	Ligurian Sea	Cc										0.00062	2			#2-3			1990-1997	PS	17
PLL	SWO	Morocco			3581					some	76.8											I	14
PLL	SWO	Spain		Cc	22225-23637						6.12			4.468	367	48.8 (392)	15	J, 9	SQ, M, SA		1991	O	1
PLL	SWO	Spain		Cc	35637						9.8				655	47.4 (473)	15	J, 9	SQ, M, SA		1990	O	1
PLL	SWO	Spain		Cc				0.36							1098	(27-76; 865)	15	J, 9	SQ, M, SA		1990-1991	O	1
PLL "BFT"	BFT	Spain						1.74				2.7		1.410	746						1999-2004	O	6
PLL "BFTr"	BFT	Spain						1.85				1.74		1.057	54						1999-2004	O	6
PLL "SWA"	SWO	Spain						1.60				0.86		0.690	125						1999-2004	O	6
PLL "SWB"	SWO	Spain						0.54				2.29		0.740	1837						1999-2004	O	6
PLL "SWBr"	SWO	Spain						4.24				1.68		1.360	354						1999-2004	O	6
PLL "ALB"	ALB	Spain						1.41				5.057		1.180	354						1999-2004	O	6
PLL	SWO	Spain	<10 nm											0.100			23.6	J, 7 (Mustad #1)	SQ, M		2000-2003	O	3
PLL	SWO	Spain	10-35 nm	Cc										1.000	675		23.6	J, 7 (Mustad #1)	SQ, M		2000-2003	O	3
PLL	SWO	Spain	>35 nm											4.480			23.6	J, 7 (Mustad #1)	SQ, M		2000-2003	O	3
PLL "LLHB"	SWO	Spain		Cc				0.65		No		2.551		0.847	1380	52.6 (29.5-79.2; 337)		J, 7.1-9	SA, M, SQ	In part	1999-2000	O	5
PLL "LLHB"	SWO	Spain		Dc				0.00		No		0.004		0.001	2			J, 7.1-9	SA, M, SQ	In part	1999-2000	O	5
PLL "LLALB"	ALB	Spain		Cc	1858 (d)	626	3090	1.41		No		5.057		1.184	354	39.1 (20.5-79.0; 117)	7-24	J, 3.7-4.4	SA, M	No	1999-2000	O	5
PLL "LLJAP"	BFT	Spain		Cc				3.32		No		2.459		1.639	391	54.8 (36.1-72.3; 221)		6.6-7.3	M, SQ	In part	1999-2000	O	5
SPLL "LLPB"	SWO	Spain								No		0.000		0.000	0			J, 8.1-9	M, SQ	No	1999-2000	O	5
PLL		Spain	North		130	38	222						1.200									O/I	2
DLL		Spain	North		negligible								0.010									O/I	2
DLL		Spain	Balearic islands		8	0	24						0.010		8						2002	I	7
PLL		Spain	Balearic islands		102	93	111	7.7					4.665		70						2002	I	7
PLL	shark	Tunisia	Gulf of Gabes	Cc	486			0 (9.1) (e)	0 (44) (e)			0.70213		0.823	33	58.5 (33)		J, 9.8-11.1	M, B		2004-2005	O	12
DLL	grouper	Tunisia	Gulf of Gabes	Cc	733			12.5 (33) (e)	92 (244) (e)			0.72727		0.278	24	48.7 (24)		J, 7.8	P, SE		2004-2005	O	12
DLL		Tunisia			2000			0.53			22.83				753							I	4

Gear, PLL: Pelagic Longline; BLL: Demersal Longline, SPLL: Set Pelagic Longline. Specific names appearing in the original reports are provided too. **Target species**, BFT: Bluefin Tuna; SWO: Swordfish; ALB: Albacore; DF: Demersal Fish. **Turtle species**, Cc: *Caretta caretta*; Cm: *Chelonia mydas*; Dc: *Dermochelys coriacea*. **Bait**, M: Mackerel; P: Pilchard; SQ: Squid; SA: Sardina, B: Bogue (*Boops boops*), SE: cuttlefish (*Sepia officinalis*). **Method**, I: Interview; O: Onboard observation; L: Logbook; PS: Port survey. **Vertical bars** indicate that values on the right refer to multiple raws

Source: 1: Aguilar et al., 1995; 2: Alvarez de Quevedo et al., 2006; 3: Baez et al., 2007b; 4: Bradai, 1993; 5: Caminas and Valeiras, 2001; 6: Caminas et al., 2006; 7: Carreras et al., 2004; 8: Casale et al., 2007a; 9: De Metrio et al., 1983; 10: Deflorio et al., 2005; 11: Guglielmi et al., 2000; 12: Jribi et al., 2008; 13: Kapantagakis, 2001, Kapantagakis and Lioudakis, 2006; 14: Laurent, 1990; 15: Nannarelli et al., 2007; 16: Nada and Casale, 2008; 17: Orsi Relini et al., 1999; 18: Panou et al., 1999. **Notes**: a: from the Strait of Sicily to the Libyan Sea; b: dead or almost dead; c: mean 1999-2000; d: only for vessels >12 m; e: considering as potential mortality those turtles found in comatose state.

Table 7-3. Review of data about turtle capture by set netters in the Mediterranean. Countries are listed per fishing gear and in alphabetical order.

Gear	Target species	Country fleet	Area	Turtle Species	Captures/yr	CI 95%	Dead (%)	Deaths/ yr	Intentional killing	Turtles/ year- boat	Turtles/ month- boat	Turtles/ day-boat	Turtles/day- km	Turtles/ yr-km	N turtles	Turtle CCL (cm) Avg (range; n)	Boat lenght (m)	Depth (m) (fishing effort)	Study period	Method	Source
SN		Croatia/Slovenia					54.9								51				2000-2002		11
SN		Croatia					62.5								8					TR	12
SN (TN+GN)		Croatia/Slovenia			657-4038		57.9			2.81				1.11	92				2000-2005	I	13
SN		Egypt		Cc, Cm	754				many										2007	I	14
SN (TN)	S	France	mainland				53.1			1.77-2.18					128	39.3 (35.5-48.6; 4)		0-10	1990	I	9, 10
SN (GN)		France	mainland				33.3			0.8					6			< 50	1990	I	9
SN (TN)		France	mainland				28.6			0.12					9				1990	I	9
SN (TN)	L	France	mainland				100								8				1990	I	9
SN (TN)	L	France	Corsica	Cc			87.5		yes						16			60-110	1985	I	6
SN (TN)	O, L	France	Corsica	Cc			50								6			8-80	1985	I	6
SN		Italy + other Med.					45.5								11	45.8 (21-80; 70)				TR	4
SN (TN)	L	Spain	Balearic isls.		196	123 269	77.7				0.17				45					O/I	3
SN (TN)	M	Spain	Balearic isls.		6	0 15	50				0.009				2					O/I	3
SN (TN)		Spain			65	35 95					0.02									O/I	1
SN (TN)		Tunisia			2000		5.17			0.92					58					I	2
DN		Italy	Ionian		16000		29					3-50			31					L	5
DN	SWO	Italy	Ligurian/Thyrrhenian				0					0.05			5				1990-1991	O	7
DN	SWO	Spain		Dc			0					0.065	0.016-0.018		2				1993-1994	O	15*
DN	SWO	Spain		Cc	236	117 354	3.3					0.968	0.24-0.27		30				1993-1994	O	15*
DN		Tunisia								0.6										I	2
LL/SN		Cyprus	north coast		684		10	69	yes	4							4-10		1995	I	8
LL/SN		Turkey	Levantine Basin		1328		10	133	yes	2.5							4-10		1995	I	8

Gear, SN: Set Net; DN: Drifting Net; LL: Longline; TN: Trammel Net; GN: Gill Net.
Target Species, S: Sole (Solea solea); L: Spiny lobster (Palinurus elephas); M: Red Mullet; SWO: Swordfish; O: Other.
Method, I: Interview; O: Onboard observation; L: Logbook; TR: Tag Returns
Source, 1: Alvarez de Quevedo et al., 2006; 2: Bradai, 1993; 3: Carreras et al., 2004; 4: Casale et al., 2005b; 5: De Metrio and Megalofonou, 1988; 6: Delaugerre, 1987; 7: Di Natale et al., 1995; 8: Godley et al., 1998; 9: Laurent, 1991; 10: Laurent, 1996; 11: Lazar and Tvrtkovic, 2003; 12: Lazar et al., 2004a; 13: Lazar et al., 2006; 14: Nada and Casale, 2008; 15: Silvani et al., 1999.
*****Calculated from data in other form

Table 7-5. Estimate of total turtle captures by pelagic longliners in the Mediterranean. Countries are listed in geographical order (clockwise).

Target species	Country	Area	Catch Rate A	Unit	Source	Year	Conv. fact.	Unit	Sour ce	Catch Rate B	Unit	Fishing effort/yr	Unit	Year	Source	Total captures/yr
	Spain	North (Cataluna)	1.2	T/M	Tab 7-2	? Recent						108	M	? Recent	1	130
	Spain	Balearic	4.665	T/M	Tab 7-2	2002						15		2002	2	102
	Spain	SPA-S	2.4	T/D	Tab 7-2 (a)	1999-2004	90	D/Y	's by 1	216	T/Y	88	V	2006	3	19,008
	France		1.2	T/M	Spain - North	? Recent	3	M/Y	rbitrar	3.6	T/Y	88	V	2006	3	317
	Monaco		?									?				
	Italy	ITA-T	0.1	T/1000 H	Tab 7-2 (b)		71	1000 H/Y	and 1	7.1	T/Y	712	V	2006	4	5,055
SWO	Italy	North Ionian	0.2069	T/D	Tab 7-2	1999-2000						?		1999-2000	Tab 7-2	156
SWO	Italy	South Ionian	0.535	T/D	Tab 7-2	1999-2000						?		1999-2000	Tab 7-2	1,497
ALB	Italy	North Ionian	0.803	T/D	Tab 7-2	1999-2000						?		1999-2000	Tab 7-2	326
ALB	Italy	South Ionian	0.560	T/D	Tab 7-2	1999-2000						?		1999-2000	Tab 7-2	1,074
SWO	Italy	Central Med	27.2	T/Y	Tab 7-2	2005								2005	Tab 7-2	2,148
	Malta		27.2	T/Y	Italy Central Med	2005						109	V	2006	3	2,965
	Slovenia		?									0	V	2006	3	0
	Croatia		?									?				
	Bosnia and Herzegovina		?									?				
	Montenegro		?									?				
	Albania		?									?				
SWO	Greece	East Ionian/Aegean	0.086	T/D	Tab 7-2	1999-2000								1999-2000	Tab 7-2	3,310
	Turkey		?									?				
	Cyprus		?									31	V	2006	3	
	Syria		?									?				
	Lebanon		?									?				
	Israel		?									?				
	Egypt		?									?				
	Libya		27.2	T/Y	Italy Central Med	2005						42	V	2000	5	1,142
Shark	Tunisia		0.7	T/D	Tab 7-2	2004-2005									6	1,000
SWO	Algeria		2.8	T/Y	Tab 7-2	1990						105	V	2000	5	294
SWO	Morocco		76.8	T/Y	Tab 7-2	1990						193	V	2003	7	14,822
	Total															53,347

Target species, SWO: Swordfish; ALB: Albacore.

Area, SPA-S South (Comunidad Valenciana, Murcia, Andalucia (Mediterranean side), Ceuta & Melilla); ITA-T Thyrrenian (Liguria, Toscana, Lazio, Campania, Calabria), Sicily, Sardinia.

Unit: T: Turtle; D: day; M: month; Y: year; H: Hook; V: vessel.

Conv. Fact: Coversion factor from Catch Rate A to Catch Rate B.

Source: 1: Alvarez de Quevedo et al., 2006; 2: Carreras et al., 2004; 3: EU Fleet Register; 4: 3846 vessels are registered as bottom longliners (EU Fleet Register) but no one as pelagic longline, so they should be considered as generic longliners. The proportion pelagic/total longliners observed in the field in Sicily is 18.5% (Guglielmi et al., 2000); 5: Copemed, www.faocopemed.org; 6: Arbitrary and conservative: the double of the captures estimated for the port of Zarzis only; 7: Benhardouze, 2004: 399 (on the "Mediterranean side" including Tanger) - 206 (Tanger) =193.

Notes: (a) mean of values reported by Caminas et al. (2006) for the 6 types of drfting longlines (Tab. 7-2); (b) mean value between Ligurian Sea and S Thyrrenian; Tab. 7-2.

Table 7-6. Estimate of total turtle captures by demersal longliners in the Mediterranean. Countries are listed in geographical order (clockwise).

Country	Area	Catch Rate A	Unit	Source	Year	Conv. fact.	Unit	Source	Catch Rate B	Unit	Fishing effort/yr	Unit	Year	Source	Total captures/yr	Known Catch Rates	Known and conservative CRs
Spain	North	0.01	T/M	Tab. 7-2							784	M	? Recent	3	8	8	8
Spain	Balearic	0.01	T/M	Tab. 7-2							837	M	2002	4	8	8	8
Spain	SPA-S	0.5	T/Y	CV							135	V	2006	5	68		68
France	Mainland	0.01	T/M	Spain	2002-?recent	10	M/Y	Arbitrary	0.1	T/Y	224	V	2006	5	22	22	22
France	Corsica	0.01	T/M	Spain	2002-?recent	10	M/Y	Arbitrary	0.1	T/Y	21	V	2006	5	2	2	2
Monaco		?									?						
Italy		0.5	T/Y	CV							5289	V	2006	5	2,645		2,645
Italy	Lampedusa	0.786	T/D	Tab. 7-2	2005						327	D	2005	6	257		
Malta		0.5	T/Y	CV							572	V	2006	5	286	286	286
Slovenia		?									0	V	2006	5		0	0
Croatia		?									?						
Bosnia		?									?						
Bosnia and Herzegovina		?									?						
Albania		?									?						
Greece		0.5	T/Y	CV							12127	V	2006	5	6,064		6,064
Turkey		2.5	T/Y	1							2000	V	2005	7	5,000	5,000	5,000
Cyprus		4	T/Y	1							?						
Syria		?									?						
Lebanon		?									?						
Israel		?									?						
Egypt		1.9	T/Y	Tab. 7-2							1120	V	2004	8	2,128	2,128	2,128
Libya		2	T/Y	2							6689	V	2000	9	13,378		13,378
Tunisia		0.72	T/D	Tab. 7-2	2004-2005									10	1,500	1,500	1,500
Algeria		0.5	T/Y	CV							175	V	2000	9	88	88	88
Morocco		0.5	T/Y	CV							6731	V	2000	11	3,366	3,366	3,366
Total																**12,408**	**34,561**

Area, SPA-S South (Comunidad Valenciana, Murcia, Andalucia (Mediterranean side), Ceuta & Melilla).

Unit: T: Turtle; D: day; M: month; Y: year; H: Hook; V: vessel.

Conv. Fact: Coversion factor from Catch Rate A to Catch Rate B.

Source : CV: arbitrary conservative value; 1: Tab 7-2. Catch rates of BLL and SN are assumed to be the same; 2: Plausible conservative value on the basis of values from Egypt and Tunisia; 3: Alvarez de Quevedo et al., 2006; 4: Carreras et al., 2004; 5: EU Fleet Register; 6: Casale et al 2007a; 7: Conservatively considered as 2000 out of 8146 vessels other than BT and PS (PLL, BLL and SN) of Turkey. (Prime Ministry Republic of Turkey, Turkish Statistical Institute, Fishery Statistics 2006.); 8: General Authority for Fisheries Resources Development, Egypt; 9: Copemed, www.faocopemed.org; 10: Arbitrary and conservative: the double of the captures estimated for the port of Zarzis only; 11: All longliners; Copemed, www.faocopemed.org.

Table 7-8. Summary of total captures by different fishing gear in the Mediterranean, according to source (known or known + conservative estimates) and ranges of catch rates (Tables 7-4, 7-5, 7-6, 7-7), and associated mortality on the basis of given Mortality Rates (§ 7.3.2., 7.4.2., 7.5.2., 7.6.2.).

	Mortality rate	**Captures/year**				**Deaths/year**			
Catch Rate source		**Known**		**Known + conservative**		**Known**		**Known + conservative**	
Catch Rate		**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Bottom trawl	20%	35,003	88,557	36,833	90,447	7,001	17,711	7,367	18,089
Pelagic longline	40%	53,347	53,347	53,347	53,347	21,339	21,339	21,339	21,339
Demersal longline	40%	12,408	12,408	34,561	34,561	4,963	4,963	13,824	13,824
Set net	60%	16,378	19,758	27,982	31,362	9,827	11,855	16,789	18,817
Total		117,135	174,069	152,723	209,717	43,129	55,868	59,319	72,070

8. Conservation measures and strategies for marine turtles in the Mediterranean

8.1. Trawl

8.1.1. Reduce captures: Turtle Excluder Devices (TED)

The measure for reducing the impact of trawlers on sea turtle populations that has been implemented in several countries (outside the Mediterranean) is the implementation of TED (§ 3.1.4.2.). However TED was designed for shrimp trawling while in the Mediterranean larger species are often targeted, making its implementation questionable (Laurent et al., 1996; Casale et al., 2004). A type of TED was developed in the USA for trawlers targeting the flounder (*Paralichthys dentatus*) (Mitchell et al., 1995). In the Mediterranean, a TED for prawn trawling in Turkey has been designed and preliminary tested (Atabay and Taskavac, 2001), but there are no conclusive data about the effects on turtle bycatch. Another TED was designed and tested in the central Adriatic, and preliminary results indicate limited loss of commercial species and discharge of large quantity of debris, so improving the overall fishing efficiency and quality (Lucchetti et al., 2008).

8.1.2. Reduce post-release mortality: awareness campaign about on-board procedures

Turtles found in comatose state, and so likely to drawn if released in this condition (PMR), have been observed in proportions higher than RMR in several cases (Table 7-1). This suggests that reducing PMR through a wide awareness campaign on the appropriate on-board procedures (§ 3.1.4.3.) can have important conservation results. Moreover, since the efficiency of TEDs depend on their correct use by the fishermen (§ 3.1.4.2.), their good will is a necessary prerequisite in any case.

8.1.3. Reduce captures: area/season closure

The overall impact of trawling would be reduced by avoiding areas were turtles concentrate in high numbers (high CRs):

- trawling should not be allowed in the marine areas around important nesting sites (Table 4-1) and during the reproductive season, because adults concentrate in these areas.
- trawling should be regulated or banned in areas with very high probability of turtle capture. For instance, dietary analyses suggest that the carnivorous loggerhead turtles feed preferably on or near seagrass beds (Casale et al., in press a). Naturally, sea grass beds are also food for the herbivorous green turtles. These beds represent very important marine communities and their protection should be a conservation priority in general.
- Trawling effort should be reduced and wherever possible not be allowed in waters shallower than 50 m. In fact turtles feeding on the benthos prefer relatively shallow waters, so that higher turtle concentration are expected there than in deeper waters. These turtles usually include the large individuals with high reproductive value. Moreover, seagrass beds (previous point) are usually in shallow waters.

Controlling the implementation of this measure requires monitoring vessels through a satellite system, like the Vessel Monitoring System by the European Union (Commission Regulation (EC) No 2244/2003) which is mandatory for all vessels exceeding 15 m overall length.

8.1.4. Reduce captures: reduction of illegal fishing

A reduction of fishing effort and so of the number of captures can be achieved through reduction of the illegal fishing effort, through enforcement of existing regulations. For instance, where the fishing ban in waters shallower that 50 m (§ 8.1.3.) already exists, it should be enforced if there is evidence of illegal fishing.

8.1.5. Reduce captures: reduction of fishing effort

Apart from turtles, intensive trawling is destructive for benthic habitats and in several countries, e.g. of the EU, trawling is considered as not sustainable (e.g. Smith et al., 2000; Tudela, 2004). Moreover, several countries are developing their fisheries, and so they are increasing the fishing effort and the impact on sea turtle populations. For this reason, a long-term ecosystem-based management (EBM) of fisheries should be pursued.

8.2. Pelagic longline

8.2.1. Reduce captures: gear modifications

8.2.1.1. Bait

Among the promising measures to reduce CR (§ 3.2.4.2.), switching bait from squid to mackerel can have just limited effects because (i) mackerel is already used by many Mediterranean longliners, (ii) probably to reduce CR the mackerel should be big (§ 3.2.4.2.), while several reasons including the cost and the size of target species may make fishermen prefer small mackerels. For instance, mackerels of 200-300 g are used in the southern Italy (Guglielmi et al., 2000). Since it is very difficult to control this parameter, the effectiveness of this measure is questionable.

8.2.1.2. Hook

Large circle hooks have proven to be effective in reducing CR in other areas, and they should be adequately tested in the several Mediterranean fisheries, together with an estimation of mortality rate they induce (see § 3.2.4.3). If proven to be effective, this is a measure very easy to control at port for correct implementation.

8.2.1.3. Depth

Intrinsically, deep hooks are probably the best solution for turtles, as based on a vertical distribution depending on the biological features of the species, and so likely to hold in any area. So it should be tested in the Mediterranean to assess the effect on the catch of target species. If proven to be effective, this is a measure that is possible to control at port for correct implementation, although it requires to measure the gear components.

8.2.2. Reduce post-release mortality: awareness campaign about on-board procedures

Reducing PMR through dehooking or at least through cutting the line short (§ 3.2.4.3.), can be effective to some extent. However, dehooking requires to bring the turtle onboard which is time consuming and not desirable for the fishermen (Guglielmi et al., 2000; Caminas and Valeiras, 2001) and it is unlikely to be largely adopted in small vessels with few crew, while cutting the line short is more feasible. Moreover, the success of the implementation of other measures depend in part on the fishermen good will, so that awareness campaigns are a necessary prerequisite in any case.

8.2.3. Reduce captures: restrict operations to night time

In the Spanish fishery, Baez et al. (2007a) observed that most turtles are captured during daylight, probably due to visual location of baits, while capture of target species are not affected by the time. This can be a good solution especially for those vessels making only one set per day. In this case, control would be very easy at port, basing on time of return. On the contrary, this could be a measure not acceptable for vessels that use to make trips of more than one days with multiple sets. In this case the time of operations would also be much more difficult or almost impossible to control at sea.

8.2.4. Reduce captures: area/season closure

Specifically for the Spanish fishery, a very promising measure is to restrict fishing within 35 nm from the coast, since in the zone farther than 35 nm turtle catch rate increases by over four times, but current fishing effort is 18% and catch rates of target species are the same in the two area (Baez et al., 2007b). Thus, fishing within 35 nm theoretically would not affect target species catch, while it would reduce greatly the turtle captures. Given the number of captures estimated for the Spanish fleet, this would represent an important contribution to the conservation of sea turtle populations in the region.
Similar distribution patterns of turtles and target species may occur in other Mediterranean areas, and this should be investigated.
Controlling the implementation of this measure requires monitoring vessels through a satellite system, like the Vessel Monitoring System by the European Union (Commission Regulation (EC) No 2244/2003) which is mandatory for all vessels exceeding 15 m overall length.
Apart this length threshold by the EU, the use of VMS for small boats may be not cost-effective, and it should be considered that many Mediterranean longliners are rather small.

8.2.5. Reduce captures: lightsticks

At the present state of knowledge (§ 3.2.4.2.), the use of lightsticks should be reduced or banned and their further diffusion among the Mediterranean longline fisheries should be avoided.

8.2.6. Reduce captures: reduction of illegal fishing

A reduction of fishing effort and so of the number of captures can be achieved through reduction of the illegal fishing effort, where and if it occurs.

8.2.7. Reduce captures: reduction of fishing effort

Apart from turtles, intensive fishing is impacting target species and other bycatch species as well. Moreover, several countries are developing their fisheries, and so they are increasing the fishing effort and the impact on sea turtle populations. For this reason, a long-term ecosystem-based management (EBM) of fisheries should be pursued.

8.3. Demersal longline

Differently from pelagic longline, turtles caught by demersal longline can drawn, resulting in a high RMR (§ 3.2.2.). At present there are no proposed solutions to reduce this mortality.

8.3.1. Reduce captures: gear modifications

It is uncertain if circle hooks may be effective for demersal longline too. The problem is the typical small size of target species and the small size of the hooks used by this gear so that the feasibility of increasing hook size for reducing turtle CR is questionable and should be investigated. However, it is possible that the small hooks of demersal longline are much less harmful than the large hooks of pelagic longline, and if so, other mortality factors should be addressed.

8.3.2. Reduce post-release mortality: awareness campaign about on-board procedures

Reducing PMR through dehooking or at least through cutting the line short (§ 3.2.4.3.), can be effective to some extent. However, dehooking requires to bring the turtle onboard and it is unlikely to be largely adopted in small vessels with few crew, while cutting the line short is more feasible. Moreover, the success of the implementation of other measures depend in part on the fishermen good will, so that awareness campaigns are a necessary prerequisite in any case.

8.3.3. Reduce captures: area/season closure

Using fishing gear potentially harmful for sea turtles, including demersal longline, should not be allowed in the marine areas around important nesting sites (Table 4-1) and during the reproductive season, because adults concentrate there.

8.3.4. Reduce captures: reduction of illegal fishing

A reduction of fishing effort and so of the number of captures can be achieved through reduction of the illegal fishing effort, where and if it occurs.

8.3.5. Reduce captures: reduction of fishing effort

Apart from turtles, intensive fishing is impacting target species and other bycatch species as well. Moreover, several countries are developing their fisheries, and so they are increasing the fishing effort and the impact on sea turtle populations. For this reason, a long-term ecosystem-based management (EBM) of fisheries should be pursued.

8.4. Set net

At present, no specific solutions are available to reduce the impact of set nets, which are very poorly studied for interaction with sea turtles. There can be only generic solution as for other fishing gear.

8.4.1. Reduce captures: area/season closure

Using fishing gear potentially harmful for sea turtles, including set nets, should not be allowed at least in the marine areas around important nesting sites (Table 4-1) and during the reproductive season, because adults concentrate there. Other areas with high turtle concentration could be identified.

8.4.2. Reduce captures: reduction of illegal fishing

A reduction of fishing effort and so of the number of captures can be achieved through reduction of the illegal fishing effort, where and if it occurs.

8.4.3. Reduce captures: reduction of fishing effort

Set nets are probably the most simple and widespread artisanal fishing gear. Apart from turtles, intensive fishing is impacting target species and other bycatch species as well. Moreover, several countries are developing their fisheries, and so they are increasing the fishing effort and the impact on sea turtle populations. For this reason, a long-term ecosystem-based management (EBM) of fisheries should be pursued.

8.5. Intentional killing

Intentional killing may vanish other approaches, both because turtles are killed and because it is an evidence of lack of interest in turtle conservation by the fishermen, while the implementation of some measures require their good will and collaboration.

8.5.1. Enforcement

The most obvious measure is to enforce existent regulations. While this is fundamental both to show interest by the authorities in conserving sea turtles and to guarantee equity among fishermen, it should not be assumed to be always sufficient to reduce intentional killing. In fact, it can occur in circumstances difficult to control, notably on board (§ 7.7.).

8.5.2. Awareness campaign

Removing the drivers of intentional killing should be considered the first step, associated with enforcement, in all the fisheries where this phenomenon occur. It should also taken into account that intentional killing occurs among artisanal fishermen in particular.

8.6. Ghost gear

At present an important impact of ghost gear on sea turtles can only be hypothesized (§ 7.8.). Certainly, the accumulation of floating marine debris such as nylon lines as the result of longline loss, represents a potential threat to turtles frequenting for trophic reasons areas where currents converge and accumulate debris, because turtles can easily get entangled.

In general, investigating ways to reduce this debris, e.g. degradable lines, may benefit turtles as well as other species.

9. Conclusions and recommendations

Although with a high degree of uncertainty, the present analysis shows that in the Mediterranean sea turtle bycatch is high (over 150,000 per year), with a high number of deaths too, probably over 50,000 per year. Moreover, many are killed intentionally and probably many are killed by ghost gear too.

However, the lack of adequate information on population size, parameters and dynamics impedes to understand how a certain mortality affects population growth (§ 2.4.). In this situation, further research for assessing interaction or mortality is not sufficient to indicate whether or not conservation actions are necessary.
Until population dynamics of Mediterranean populations will be disclosed, under a precautionary approach mortality induced by fishing interaction should be assumed to be not sustainable and so conservation measures should be deemed as necessary.

Unfortunately, measures ready to be implemented are few, their implementation is not easy, and/or their positive effects are not assured. Among these, area closure for Spanish pelagic longline fleet is promising (§ 8.2.4.); trawling restrictions for shallow waters and in particular for seagrass beds (§ 8.1.3.) and banning lightsticks for longline (§ 8.2.5.) are promising, but acceptance by fishermen may be difficult; change longline bait is promising too, but only in those fisheries now using squids and if large mackerel are used (§ 8.2.1.1.); area/season closure for marine areas surrounding major nesting sites should be pursued (§ 8.1.3.), although it can be regarded as just a partial contribution; awareness campaign providing fishermen with procedures to reduce PMR of longline and trawl are promising (§ 8.1.2.; 8.2.2.), but how many fishermen will adopt those procedures while working alone at sea remains uncertain; reduction of illegal fishing would be valuable, but feasibility is uncertain; enforcement and awareness campaigns to contrast intentional killing (§ 8.5.) are the only way, but they are challenging.
Other measures that have been proposed should be tested in field conditions, such as circle hooks (§ 8.2.1.2.), deep hooks (§ 8.2.1.3.), nighttime longline (§ 8.2.3.), longline area closure (§ 8.2.4.), TED (§ 8.1.1.).
Finally, specific measures for mitigating the impact of demersal longline (§ 8.3.), set nets (§ 8.4.), and ghost fishing (§ 8.6.) have not been even suggested yet.

So far, the turtle bycatch problem has been addressed by studying and proposing measures for two fishing gear which are used totally (trawl) or in part (pelagic longline) by large industrial vessels.
However, present results indicate that those fishing gear suspected to cause the highest number of captures and deaths in the Mediterranean (Table 7-8) are used by small vessels (set nets, demersal longlines, part of pelagic longline).
Moreover, implementation of measures such as modifications of the fishing gear are more feasible for few large industrial vessels than for thousands of small artisanal vessels, often not even registered.
Hence, other than specific measures (often just technical) for reducing captures and/or mortality for specific gear, perhaps a new kind of strategy should be elaborated to deal with artisanal fisheries (all aspects), which appear to be so relevant for sea turtle conservation in the Mediterranean. This approach should necessarily include cultural and socio-economic aspects rather than just technical ones and pursue an ecosystem-based management of fisheries.

On the basis of the available knowledge, the following priority actions (in terms of both immediate implementation of measures already available and applied research) are proposed:

Intentional killing

- Assess the drivers of intentional killing and reduce it (Egypt, Greece, Cyprus, Syria, Tunisia, Turkey)

Pelagic longline

- Set up fishing area management/closure (Spain)
- Ban lightsticks attractive for turtles (Mediterranean)
- Where squids are used as a bait, promote change to mackerels

- Reduce post-release mortality through awareness campaigns (Spain, Italy, Morocco, Greece, Malta, Libya. Tunisia)
- Test large different hooks (e.g. large circle hooks) and deep hooks (Italy, Morocco, Greece, Malta, Tunisia, Libya, Tunisia)
- Test restriction to night time (Spain, Italy, Morocco, Greece, Malta, Libya)
- Investigate possible spatial differences in catch rates among fishing areas suitable for an area management approach (Italy, Morocco, Greece, Malta, Libya, Tunisia)

Demersal longline and set net (artisanal fisheries)

- Test different hooks (e.g. circle hooks) in demersal longline (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, and Italy)
- Reduce post-release mortality in demersal longline through awareness campaigns (pelagic longline: Spain, Italy, Morocco, Greece, Malta, Libya. Tunisia; demersal longline: Tunisia, Libya, Greece, Turkey)
- Investigate measures to reduce catch rate and mortality rate in demersal longlines (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, and Italy) and set nets (Tunisia, Libya, Greece, Turkey).
- Assess captures and mortality in demersal longlines (Libya, Greece, Turkey, Egypt, Morocco, and Italy) and set nets (Tunisia, Libya, Greece, Turkey).
- Elaborate strategies to address turtle bycatch and fishery management in artisanal fisheries (Tunisia, Libya, Greece, Turkey, Egypt, Morocco, Cyprus, Croatia)

Bottom trawl

- Reduce post-release mortality in bottom trawl through awareness campaigns (Italy, Tunisia, Croatia, Greece, Turkey, Egypt, Libya)
- Test a TED type suitable for Mediterranean target species (Italy, Tunisia, Croatia, Greece, Turkey, Egypt, Libya)
- Assess mortality rate and associated fishing parameters in bottom trawlers, useful to indicate the best mitigating measures (e.g. TED, awareness campaign) (Italy, Tunisia, Croatia, Turkey¸ Egypt, Greece, Libya).

General

- Establish marine protected areas around major nesting sites (Greece, Turkey, Cyprus, Libya)
- Promote ecosystem-based management of fisheries, especially with small-scale fisheries (Mediterranean)
- Promote reduction of fishing effort, including illegal fishing (Mediterranean)
- Collect biological data and develop population models to understand the impact of bycatch on Mediterranean sea turtles (Mediterranean)
- Develop and implement national marine turtles management and conservation plans

Marine turtles frequent different habitats and areas during their lives, and migrate long distances, so they move across many national boundaries. For this reason, international cooperation is absolutely necessary for the conservation of this species. This is particularly true for the Mediterranean; an almost enclosed basin surrounded by 21 countries, each with its own unique culture. Nesting sites, foraging and wintering grounds, and migratory routes comprise a substantial part of the basin and many different countries are important for the conservation of these animals. It is evident that long-term conservation of marine turtles in the Mediterranean is not an easy task that can be undertaken by a few countries – it requires international commitment and efforts.

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Appendix A. Glossary

Basket: unit of the longline gear, the tract between two floats, carrying several hooks
Bottom trawl: fishing gear in which a net is towed and runs over the sea bottom
Branchline: secondary line of the longline, carrying the hook
Catch rate (CR): turtles captured by a fishing effort unit (e.g. turtles/day; turtles/set)
CCL: Curved Carapace Length
Codend: the terminal bag of a trawl net.
EBM: ecosystem-based management
Fishing effort (FE): it can be reported in different units (e.g. fishing days, number of sets)
Fishing trip: from the port to the same or another port.
Float line: secondary line of longline, attached to a float
Gear-induced mortality rate (GMR)**:** mortality rate induced by the gear alone
Gillnet: net made by a single layer
Groundrope: rope of the lower part of the opening of a trawl net which is in contact with the sea bottom
Headrope: rope of the upper part of the opening of a trawl net, not in contact with the sea bottom
Intentional killing: death caused by the fishermen on turtles found alive
Intentional Mortality Rate **(IMR)**: proportion of turtles killed by the fishermen among those found alive
Mortality rate (MR): proportion of turtles dying among the total of turtles caught
Post-release Mortality Rate (PMR) (aka indirect mortality): proportion of turtles dying among the total of turtles caught and released alive
at-Retrieval Mortality Rate (RMR) (aka direct mortality): proportion of turtles found dead at the gear retrieval among the total of turtles caught
Midwater trawl: fishing gear in which a net is towed without touching the sea bottom (there are exception however, see text)
Pelagic trawl: Midwater trawl.
Sets: operation unit of longline and set net, starting with gear deployment and ending with gear retrieval
Tow: operation unit of trawling, starting with net deployment and ending with net retrieval
Trammel net: net made by three layers
Turtle Excluder Device (TED): device which makes turtles escaping from a trawl net
Weight line: secondary line of demersal longline, attached to a weight

Appendix B. Data collection for bycatch assessment

Since resources for studying bycatch are limited, it is fundamental that such efforts are optimized as much as possible. During a field survey, attention should be given to collect any parameter that can greatly improve the quality and relevance of the study. Descriptive research on bycatch should collect all the possible parameters necessary for standardization and correct estimations (see § 3.), summarized below. Surveys may be carried out through three main approaches: (i) direct observation on board; (ii) logbook (fishermen collect data and report to researchers when landing); (iii) one time survey through interviews

B. 1. Onboard observations

The following parameters should be collected whenever possible.

- Boat parameters
    - Boat ID
    - Port
    - Boat length
    - Fishing gear used during the year (which gear in which period)
    - Number of crew
    - Crew composition (nationality, and any relevant cultural aspect including religion)

- Fishing gear parameters
    - Trawl
        - Net Headrope length
        - Net mesh size
        - No. of boats towing the same net

    - Longline
        - No. of hooks
        - Size, shape, degree offset, material, model and brand of the hook
        - Length of the main line
        - Distance between hooks
        - Distance between floats
        - Number of hooks per basket
        - Length of branchlines
        - Length of float lines
        - Length of weight lines (demersal longline)
        - Bait species and size

    - Set net
        - Length
        - Height
        - Type of net (gillnet; trammel net)
        - Mesh size of the net layer(s)
        - Length of float lines
        - Length of weight lines

- Turtles
    - Turtle ID
    - Turtle size (e.g. CCLn-t; SCLmin)
    - Date and time of end of tow or set
    - Boat ID
    - Status (healthy and active; injured (describe); comatose; dead)

- Hook position (e.g.: mouth; esophagus, deeper) (longline)
- Line entanglement (longline)
- Net entanglement (set nets)

- Fishing operations
    - Trip duration (Date and time at start and return to port)
    - Tow or set duration (Date and time at deploy and retrieval)
    - Tow or set position (coordinates at deploy and retrieval)
    - Sea bottom depth at each tow or set
    - Speed during tow (trawlers)
    - Sea temperature
    - ID of any turtle captured

B.2. Logbook programmes

Most of the contents of this section are modified from a report by Casale P., Carreras C., Hamza A., Lazar B., Panagopoulou A., Pont S., Tomás J., and White M. (Casale et al., 2003b).

The following parameters should be collected whenever possible, by researchers and fishermen.

Data to be collected by researchers.

- Boat parameters
    - Boat ID
    - Port
    - Boat length
    - Fishing gear used during the year (which gear in which period)
    - Number of crew
    - Crew composition (nationality, and any relevant cultural aspects including religion)

- Fishing gear parameters
    - Trawl
        - Net Headrope length
        - Net mesh size
        - No. of boats towing the same net

    - Longline
        - No. of hooks
        - Size, shape, degree offset, material, model and brand of the hook
        - Length of the main line
        - Distance between hooks
        - Distance between floats
        - Number of hooks per basket
        - Length of branchlines
        - Length of float lines
        - Length of weight lines (demersal longline)
        - Bait species and size

    - Set net
        - Length
        - Height
        - Type of net (gillnet; trammel net)
        - Mesh size of the net layer(s)
        - Length of float lines
        - Length of weight lines

Data to be provided by the fishermen.

Trawl
on a routine basis:
- number of fishing days
- number of turtles caught

periodically:
- average haul duration
- average number of hauls per day
- headrope length

Longline
on a routine basis:
- number of fishing days
- number of turtles caught

periodically:
- average number of hooks per set
- average number of sets per day

Set net
on a routine basis:
- number of fishing days
- number of turtles caught

periodically:
- average number of sets per day

Routine data should be collected choosing an arbitrary but appropriate time interval. This interval should be a right compromise between annoying the captains and avoiding loss of notes or memory of the data. Since many fishermen stop fishing at least once a week (usually at the weekend), a possibility could be to ask them once a week, as in this case one week would be an objective working period.

The data sheet the captains could use to record data on a routine basis is fundamentally a calendar, with days in rows and number of turtles and fishing day (Y/N) in columns (see the specimen enclosed below). Normal calendars or logbooks could work as well.

Data sheet for routine data

Boat			
Month/Year			
Date	**Turtles**	**Fishing Days**	**Notes**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
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Calculation of standardized catch rates

Catch rate is calculated as:

CR = TC / FE

Where TC is the number of turtles caught during the monitored period and FE is the fishing effort in the same monitored period.

While the number of turtles caught (TC) is relatively simple to record, the fishing effort (FE), necessary to calculate catch rates, represents the real difficulty of the study. Since data are to be collected by captains on a voluntary basis they should be asked for very simple tasks. This limits the quantity and quality of data that is possible to collect. Fishing effort can be measured in different units with different levels of difficulty.

Units of fishing effort for trawl:

- Fishing days
  This fishing effort is useful to estimate the total number of captures in a fishery, because fishery statistics can provide fishing effort as fishing days or number of vessels (from which total fishing days can be calculated if the average fishing days per vessel is known).

- Headrope Length x Duration
  This a standardization adopted by studies in different areas of the world and can be useful to compare catch rates from different studies:

  $$SFE = \sum_{i=1}^{n} sh_i * sd_i$$

  where SFE is the standardized sampled fishing effort, *i* is the single tow, sh is the Standardized Headrope Length (m/30.5) and sd is the Standardized tow Duration (min/60). [the length of 30.5m and time of 60 min are arbitrary units and any other one can be adopted]

  To calculate this fishing effort the following data are needed:
  a) number of tows
  b) duration of each tow
  c) headrope length

  Headrope length (c) can be considered the same for tows using the same net, so it does not represent a problem. On the other hand, real data on (a) and (b) cannot be obtained easily, because in many cases this would require too much work for captains.
  However, a possible approach is to approximate SFE to a standardized *average* sampled fishing effort, calculated as:

  $$SFE \approx \overline{SFE} = d * \bar{se}$$

  Where d is the number of sampled fishing days and $\bar{se}$ the *average* standardized fishing effort per day:

  $$\bar{se} = sh * \bar{sd} * \bar{n}$$

where

sh is the standardized headrope length ,

$s\bar{d}$ is the standardized *average* tow duration (min/60),

$\bar{n}$ is the *average* number of tows per day.

In contrast to obtain from the captains total number of tows and tow duration of each tow, obtaining the *average* number of tows per fishing day and the *average* tow duration they adopt for an arbitrary period of time (a week, 2 weeks, one month) could be a feasible task. Certainly, standardized fishing efforts obtained in this way should not be considered of the same quality of those obtained through direct collection of data by observers on board.

Units of fishing effort for longline

- Fishing days
  This fishing effort is useful to estimate the total number of captures in a fishery, because fishery statistics can provide fishing effort as fishing days or number of vessels (from which total fishing days can be calculated if the average fishing days per vessel is known).

- Number of hooks
  This a standardization adopted by studies in different areas of the world and can be useful to compare catch rates from different studies:

  Longline is a complex fishing gear, as far as the number of parameters is concerned. For instance: hook number, hook type (size and shape), bait, float line length, branch line length, distance between two branchlines, distance between two float lines, etc. (§ 3.2.1.). This makes standardization difficult and in some cases impossible, making comparison difficult or impossible. The only standardization possible is on the number of hooks, if all the other parameters are constant or their difference is assumed to have little effect on difference in catch rates. In this case, the common unit of fishing effort is 1000 hooks.

  An average number of hooks used can be easily obtained by the captain. Alternatively, periodical counts can be carried out by the research team.

Units of fishing effort for set net

- Fishing days
  This fishing effort is useful to estimate the total number of captures in a fishery, because fishery statistics can provide fishing effort as fishing days or number of vessels (from which total fishing days can be calculated if the average fishing days per vessel is known).

- Net length (m)
  A convenient multiple can be used as a unit (e.g. 100 m, 1 km)

- Net area (m^2)
  This is calculated as length by height. A convenient multiple can be used as a unit (e.g. 100 m^2, 1 km^2)

B.3. One-time interviews

The contents of this section are modified from a report by Casale P., Carreras C., Hamza A., Lazar B., Panagopoulou A., Pont S., Tomás J., and White M. (Casale et al., 2003b).

In the case of other fishing gear with a presumed low catch rate per vessel, another approach could be used to obtain a preliminary assessment of the total catch. This approach is based on one-time interviews/questionnaires rather than on monitoring fishing activity for a period of time.
Information about number of vessels for each fishing gear used (also multiple gears) in the surveyed port is desirable.
Interviews can be done asking specific questions following a questionnaire or collecting the same information in the form of informal conservation. The best approach depends on the circumstances and fishermen attitude and should be evaluated by the researcher.
The unit of study is the vessel and only one fisherman from each boat should be interviewed. The questionnaire should concern a standard period of time (max 1 year), corresponding to the frequency of the interview.
The basic questions that should be included are: number of turtles caught by the boat in this period of time, and the effort made by the boat in the same period (months that the vessel fished).
The way fishermen are approached and interviewed can affect reliability of the answers.

The following rules may help: friendly behavior; casual dress; no questionnaires in the hand; just chat, and firstly on other topics; present the project as a scientific one, not an official inspection; never disagree, whatever the matter; do not suggest the answers; about turtles, firstly ask questions on the general fishery/fisheries, then specific questions on the fisherman's experience with turtles; "when/where/which/who" questions on interaction are preferable to "Yes/No" questions.

Main questions/data to collect are:

	Questions/data	Relevance
1	Boat length:	****
2	What kind of fishing gear did you use in the last year? (multiple answers)	****
3	In which months and area did you use each fishing gear in the last year?	***
4	In which months is possible to see sea turtles and how many in each month (few/some/many)?	*
5	In your opinion, what is the trend of the sighting frequency (decreasing/stable/increasing)?	*
6	In which months is possible to catch turtles and how many in each month (few/some/many)?	*
7	In your opinion, what is the trend of the catch frequency (decreasing/stable/increasing)?	**
8	Do you think that the involuntary catches are related to some fishing gear in particular? Which one?	**
9	In which fishing gear is more common that turtles are found dead?	***
10	How many turtles did you catch incidentally in the last year?	****
11	How many for each fishing gear?	****
12	In which months did you catch more?	***

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