A small fishery with a high impact on sea turtle populations in the eastern Mediterranean

Yaniv Levy\textsuperscript{a,b,c}, Ori Frid\textsuperscript{b,c}, Adi Weinberger\textsuperscript{b,c}, Rotem Sade\textsuperscript{b,c}, Yoav Adam\textsuperscript{b,c}, Uria Kandanyan\textsuperscript{b,c}, Victoria Berkun\textsuperscript{b,c}, Noga Perry\textsuperscript{b,e}, Dor Edelist\textsuperscript{d}, Menachem Goren\textsuperscript{e}, Shevy Bat-Sheva Rothman\textsuperscript{e}, Nir Stern\textsuperscript{e}, Dan Tchernov\textsuperscript{a} and Rilov Gil\textsuperscript{a}

\textsuperscript{a}Marine Biology Department, Leon H. Charney School of Marine Sciences, University of Haifa, Haifa, Israel; \textsuperscript{b}Israel’s Sea Turtle Rescue Center, Nature & Parks Authority, Mikhmoret, Israel; \textsuperscript{c}School for Maritime Sciences, Ruppin Academic Center, Mikhmoret, Israel; \textsuperscript{d}National Institute of Oceanography, Israel Oceanographic and Limnological Research, Haifa, Israel; \textsuperscript{e}Department of Zoology and The Steinhardt Museum of Natural History, Tel Aviv University. Tel Aviv, Israel

(Received 20 May 2015; accepted 11 September 2015; first published online 14 October 2015)

Sea turtles were targeted by fisheries in the Mediterranean from 1920 to 1970 and have undergone severe exploitation. At least 30,000 to 40,000 turtles were caught along the Palestinian coastline during the 1920s to 1930s. Although intentional capture of marine turtles is now illegal, sea turtles are still incidentally caught by the fishing industry, making it a major cause of sea turtle mortality. The present study assesses the impact of the Israeli fishery fleet on the turtle population in the Levantine basin based on on-board observations and a fishermen survey. The results show that gillnets and trawlers are the main threats to sea turtles in this area. 21 turtles were caught during 1385.5 hours of trawling observations – a catch rate of 0.015 turtles per hour. We estimate that a total of 1,315 turtles are caught annually by Israeli trawlers. According to the fishermen survey, \ensuremath{\sim}21 turtles are caught each year by a single gillnet vessel, yielding an annual estimate of 1,672 turtles for the whole gillnet fleet. We have also found that only a small fraction of the turtles injured by trawlers is represented in the strandings. The mortality rate through trawling and the stranding density is the highest in the region, emphasizing the urgent need to regulate the Israeli fishery. This fishery poses a major threat to the whole Levantine sea turtle population, especially during the vulnerable reproduction stage.

Keywords: Fishery; by-catch; Mediterranean Sea; conservation; fishing; Loggerhead Turtle, Green Turtle

Introduction

Although the intentional capture of marine turtles is now illegal in most of the countries where they occur, fisheries are still a major cause of anxiety among conservationists (Jackson, Kirby & Berger, 2001) because sea turtles are incidentally caught as a by-catch in this industry. The main items of fishing gear – gillnets, longlines and trawlers (Wallace et al., 2010) – threaten marine turtles in different ways. In US waters, for example, incidental death via shrimp trawling is the most important source of anthropogenic mortality for sea turtles (Hart, Mooreside & Crowder, 2006).

The Mediterranean Sea is frequented by three species of sea turtles: the Loggerhead Turtle (\textit{Caretta caretta}), the Green Turtle (\textit{Chelonia mydas}), and the Leatherback Turtle (\textit{Dermochelys coriacea}), of which the latter species is only rarely observed and does not
nest. Loggerhead and Green Turtles reproduce mainly in the eastern basin (Casale & Margaritoulis, 2010). Whilst Loggerheads are distributed throughout the eastern Mediterranean (Godley, Güçü, Broderick, Furness & Solomon, 1998), Green Turtles are found mostly in the Levantine basin (Kasparek, Godley, & Broderick, 2001).

Sea turtles have been targeted by fisheries in the Mediterranean and have undergone severe exploitation for decades. The first documentation is from the 1920s. The most severe cases were documented in a report on the fisheries of Palestine (Hornell, 1935) and in Iskenderun Bay in Turkey (Gruvel, 1931) during the 1930s, with an annual average of 2,000 turtles caught there during those years. As a result, the population declined, and by 1970 the trade in turtles in the region had stopped due to lack of profit (Sella, 1981). Several studies have estimated the recent turtle mortality associated with fishing in the Mediterranean, based on on-board observations by researchers (Camínàs, Báez, Valeiras & Real, 2006; Jribi, Bradai & Bouain, 2007) and interviews (Carreras et al., 2004, Moore et al., 2010, Domènech et al., 2014). These studies revealed that in the Mediterranean Sea marine turtles were mostly threatened by the main fishing gear and especially by small fisheries in the Levantine basin (Godley et al., 1998). Casale (2011) estimated that there are more than 132,000 incidental captures per year in the Mediterranean, of which more than 44,000 are lethal. Of the estimated 132,000 annual captures, more than 39,000 turtles were captured by bottom trawlers, and more than 13,000 turtles were estimated to be captured by demersal longlines. With set gillnets, although data are lacking, the estimate was over 23,000 turtles caught each year in the Mediterranean (Casale, 2011). Most of the studies mentioned above are based on data collected in the western Mediterranean and are thus not close to the main sea turtle nesting grounds, which are situated in the eastern basin (Casale & Margaritoulis, 2010). Little to no research has been done by on-board observers on the incidental captures by trawlers in this region, and only two were conducted based on questionnaire surveys: one on the small-boat-based fisheries in northern Cyprus and part of the Turkish coast in 1998 (Godley et al., 1998), and the other on an interview survey in Egypt (Nada & Casale, 2011). Both emphasized the threat from fisheries.

The present study focuses on the impact of the Israeli fishery fleet on the turtle population in the Levantine basin, a region that was once a major Mediterranean rookery (Kuller, 1999). Today, the nesting populations of Loggerheads on this coast are counted in the lower hundreds and those of Green Turtles in the tens (Kasparek et al., 2001; Casale & Margaritoulis, 2010).

**Material and Methods**

This study is based on three datasets: fishermen questionnaires, trawling observations, and strandings data collected by the Israeli Sea Turtle Rescue Center (ISTRC). The datasets were complemented with information on the size of the active fleet in Israel from the Fishery Department of the Ministry of Agriculture, in order to estimate turtle by-catch and mortality by the entire fleet.

**Fishermen survey.** The fishermen survey was conducted between February and May 2012 in over 90% of the fishing harbours along the Israeli coast. We designed a questionnaire (translation from Hebrew given in Appendix 1) specifically to identify conflicts between fishermen and sea turtles, in consultation with a professional psychologist (Shahar Eyal from the Interdisciplinary Center at Herzeliya, Israel) who specialises in creating and analysing surveys. In order to generate honest and reliable data and to assess credibility, questions were repeated and rephrased using different wording (Bradburn, Sudman & Wansink, 2004). For honesty control, the questionnaire also included questions with predefined answers that could not be true. A questionnaire that was found to be dishonest was excluded. Furthermore, fishermen were asked questions regarding their colleagues instead of themselves, in the hope of inspiring confidence and honesty in the answers given.
Fishing methods were classified under four categories: trawling, longlines, gillnets (trammel nets were also referred to as gillnets) and purse-seines. At least 70% of the trawling fleet (n=16 vessels) and 54% of the fishermen that use other fishing vessels (working mainly on small fishing boats, n=58 vessels) from all coastal areas of the Israeli Mediterranean were interviewed. Only one individual per boat was given the questionnaire, to prevent pseudo-replication. Overall, this work summarises 74 different representatives from the fishing vessels, which is 53% of all the licensed active fishery fleet along the Israeli coastline. For each fishing method, we calculated the average number of captured turtles as reported by the fishermen’s estimates. Other types of information were also analysed by dividing them into bins or categories. These included working depth, depth of sea turtle catches, months when turtles were caught, and the part of the day when turtles are mostly caught (day vs. night). The water depth data were divided into ranges in 10 m bins. Each metre reported by fishermen was assigned one point. Later, the depth ranges were divided to 10 m sections (e.g. 11-20 m) summarising all the points within each range to the broader depth distribution. The values were normalised so that an answer consisting of a range of depths will have the same weight as an answer consisting of only one depth. For example, if one fisherman pointed out a range of 10-20 m, each metre in that range was given 1/10 point. If another fisherman pointed out the depth of 20 m, this depth alone was given one point. The data ranges provided by the fishermen were then fed into broader categories of depth distributions to simplify the zones. Regarding the time in the year when most sea turtles were reported to be caught, every month was given one point per mention. All the points per range were accumulated and every range was assigned a percentage out of the total (e.g. turtles caught during May to July, each month was considered as 33.3%) and a temporal distribution of the captures was created.

**On-board trawling observations.** Catch and by-catch (including turtles) were monitored on eight trawlers during the period 2008-2012; overall, a total of 496 hauls amounting to 1,385 h was documented during that period. The trawlers studied were dragging nets (hauls) at 20 to 120 m water depth. The haul durations ranged between 1.5-5.75 h (average 2.02 h, ±0.99). The observers documented the number of turtles caught per hauling effort and described whether the turtles were alive, dead, or in a comatose state. For our survival probability calculations, the standard haul time was determined to be between 3.5-5.75 h, in order to reflect the standard hauling time in most normal fishing routines. Therefore, shorter hauls of 1.5 h, which are commonly used only for research purposes, were excluded from the calculations. The survey was carried out along the entire Israeli coastline. The home ports of the trawlers were Ashdod, Jaffa and Haifa.
Table 1. Number of fishing licenses and active licensed vessels in 2007–2010 divided into three categories: Inshore (static longline and gillnet), Pelagic (purse-seine) and Bottom Trawling (Shapiro, 2008, 2009, 2010).

| Year | Inshore | Pelagic | Trawling | Type of information |
|------|---------|---------|----------|---------------------|
| 2007 | 388     | 19      | 31       | Licenses            |
| 2009 | 519     | 28      | 30       | Licenses            |
| 2010 | 361     | 20      | 25       | Licenses            |
| 2009 | 107     | 10      | 23       | Active vessels      |
| 2010 | 106     | 10      | 22       | Active vessels      |

Strandings surveys. Sea turtle stranding data were collected during 2008-2012. Stranding incidences were reported by different sources: municipality telephone service centres, lifeguards, beach walkers, fishermen, the navy, as well as other coastal-related workers. The reports were collected by ISTRC’s team after ensuring that there was no duplicate reporting for any of the turtles. The reports were transferred by telephone, ISTRC interactive webpage or ISTRC Facebook page. Many of the strandings were reported by Nature and Parks Authority rangers conducting coastal surveys, who also validated the civilian reports. Each stranded turtle was measured, photographed and registered in the ISTRC files. After a turtle was reported, its carcase was marked with a coloured spray or removed from the area to avoid report duplication. During the nesting season (mid-May to August), all 180 km of Israel’s coastline were examined by the rangers with roughly equal effort. From each stranded turtle report, the following parameters were collected: species, size, location and date. In some cases, due to the severely decomposed condition, species data could not be collected. Turtles that were stranded alive were brought to ISTRC for medical treatment. Their data were also collected for this study because those turtles would have died soon after stranding if they had not been brought to the ISTRC. Similarly, data were collected from cases when turtles where brought to ISTRC by fishermen who caught them.

Fishery fleet size. The Israel Fishery Department (IFD) annually surveys the number of boats operating under three fishing categories: trawlers, inshore, and pelagic. The pelagic category includes only the purse-seine fishing method. The inshore category, however, does not specify whether the gillnet or longline fishing method was used. The number of licensed fishing vessels was recorded for 1998–2010, but data from 2008 and 2011–2012 are missing. From 2009 to 2010, IFD added a new category of “active vessels” that represents the number of active licensed vessels among all licenses given, and this is therefore more relevant for our analysis (Table 1). To extrapolate fishery-related mortality for the entire fleet, we used the number of active boats in 2009, which represents the fishery fleet size during 2008–2012 when trawling observers collected the data. The change in the number of vessels from year to year was negligible, making the 2009 vessel data acceptable for the whole research period; moreover, this was the only year when the inshore category was accurately divided into gillnet and longline fishing, enabling a better comparison with the fishermen survey data that included all four fishing methods (Table 1).

Data extrapolation. The fishermen surveys provide temporal and spatial assessments of the number of turtles caught per boat by the different fishing methods. We multiplied these results by the number of active fishing boats, as derived from the fishery fleet size data, to provide an estimate of the fishery impact on sea turtle populations. To strengthen the fishermen’s estimates and credibility, we compared the fishermen’s estimates on turtles caught by trawlers with data from on-board trawling observations. In addition, we compared the turtle catch estimates from the fishermen surveys with the number of turtles stranded on Israel’s coastline from the strandings survey data.

Global comparisons. In order to standardise our data and place the results of by-catch and mortality rates on the Israeli coast into a global perspective, we have conducted a literature review of
turtle strandings, by-catch and mortality rates data that were collected globally. The data were standardised by compiling the number of stranded turtles per year from different regions worldwide. In areas where clarification regarding the data was required, we communicated directly with the authors (cf. Table 3). The annual average of stranded turtles was then divided by the relevant coastal length (km) for standardisation and comparison. In order to compare these data with the turtle capture in our region, we multiplied mortality rates in different regions by the estimated by-catch per method in Israel (Table 4).

Results

Fishermen surveys

Survey credibility. We found a strong correlation (94%) between the number of strandings per month and the results of the fishermen survey on turtle catches during these months, with an increase during May-July, which indicates that the fishermen survey is reliable (Figure 1). As 93% of fishermen replied that they often catch turtles with a curved carapace length longer than 50 cm for Loggerheads and 70 cm for Green Turtles (which matches the difference in adult size of the two species), we infer that fishermen pay attention to the species captured, also noticing their size. Another method we used to assess the survey’s credibility was by asking fishermen to point out which of the sea turtles they encounter based on four different photos. 88% and 63% of the fishermen correctly pointed out Loggerhead and Green Turtles, respectively (each fisherman could point out more than one photo). Those species are indeed the ones spotted most frequently in the area. D. coriacea, which is rarely observed in the area, was pointed out by 17%, and the Flatback turtle (Natator depressus), which is not a local species, was...
pointed out by only 4% of the fishermen. Regarding numbers of turtles caught, we noted that fishermen may give lower estimated numbers than they really remember because sea turtles are protected by law and capturing them is illegal. At the same time, some of them could be overestimating the numbers in order to boast.

**Total turtle catch estimate from fishermen surveys.** According to the questionnaire, the method with the highest amount of sea turtle by-catch per vessel is trawling, with an average of 48.9 (±5.4) turtles per boat per year, followed by gillnets: 20.9(±5), purse-seiners: 6.7 (±1.4), and static long-liners 4.8 (± 0.6) (Figure 2). Multiplying the number of caught turtles per vessel by the number of active vessels yields an estimate of the total impact of the different fishing methods.

The Fishery Department determined that 23 trawling, 10 pelagic (purse seine), 80 gillnet, and 27 longline vessels were licensed and active in the years in question (Table 1). When multiplying the estimated catch per boat by the number of boats, gillnet fishing is responsible for most turtle by-catch with an estimated 1,672 turtles caught per year, followed by trawling with 1,125 turtles, while the longline and purse-seine methods have a lower catch rate of 129 and 67 turtles per year, respectively. In total, 2,993 turtles are estimated to be caught annually by the licensed, active, fishery fleet along Israel’s coastline based on the fishermen surveys (Figure 2).

Fishermen reported that most turtle by-catch occurs at depths shallower than 50 m. More than 70% of the animals are caught within a narrower range of 0-20 m (Figure 3). 75% of trawling vessels indicated that most sea turtle by-catch occurs at night. Apparently, most of the trawling effort at night concentrates on shallow depths (<40 m), while daytime trawling has a wider range, reaching a depth of 400 m (Figure 4).

**On-board trawling observations**
A total of 1,385.5 h of trawler observations was conducted. During these observations, 21 turtles were caught. This means that 0.015 turtles were caught per hour, or that every

---

**Figure 3.** Percentage of turtles caught per depth range estimated from interviewed fishermen, for all fishing methods. N=48 interviewed fishermen.
Table 2. Cause of injury in Loggerhead and Green Turtles treated by ISTRC during 1999–2014, n=313. No. = Number of turtles. *Some of the artisanal fishermen in the Levant deliberately hurt turtles in order to reduce competition, to reduce damage to their fishing gear (their main working asset), to prevent the turtles from rocking the boat, and out of frustration upon realizing that their big catch has no commercial value.

| Cause of injury | Direct known cause of injury | Evaluated sources | No. | %  |
|----------------|-----------------------------|-------------------|-----|----|
| **Fishery**    |                             |                   |     |    |
| Purse seine    | Purse seine                 |                   | 0   |    |
| Gillnet        | Gillnet                     |                   | 34  | 54 |
| Trawler        | Trawler                     |                   | 15  |    |
| Longline       | Longline                    |                   | 50  |    |
| Hook           | Angling, longline           |                   | 16  |    |
| Drowning       | Trawler, longline, gillnet  |                   | 6   |    |
| Deliberate injury by men | Longline, gillnet *(artisanal fishermen) | | 14 |    |
| Entanglement and digestive obstruction by fishing-lines | Gillnet, angling, longline | | 33 |    |
| **Human interference impacts** |                         |                   |     |    |
| Digestive blockage | Plastics and other artificial debris | | 7 | 21 |
| Tangled in human debris | Ropes, sacks | | 25 |    |
| For sale | Illegal captivity | | 1 |    |
| Propeller and marine vessels injury | Marine vessel injury | | 32 |    |
| **Energy infrastructure** |                         |                   |     |    |
| Tar            | Pollution                   |                   | 8   | 16 |
| Soft tissue trauma | Seismic surveys, explosions, constructions | | 19 |    |
| Desalination plants and sea water filters in power stations | Desalination plants and power stations | | 22 | 10 |
| **Natural**    |                             |                   |     |    |
| Animal bite    |                             |                   | 11  |    |
| Disease        |                             |                   | 20  |    |
| **Total**      |                             |                   | 313 |    |

66 hauling hours, one turtle is caught. We used a low estimate of 180 annual working days per trawler (based on the number of days when weather permitted trawling in the region, combined with estimated boat repair time) – each working day is considered the full 24 h – multiplied by 23 active vessels. This method yielded an estimated total of 1,506 turtles caught by Israeli trawlers each year.

In standard hauls (3.5–5.75 h), 17 turtles were caught. Eight were found dead (47.1%); seven were alive (41.2%) and two in critical condition. Therefore, out of an estimated annual by-catch of 1,506 turtles by trawling, approximately 700 die during the haul and 620 are returned alive to the water. When the two by-catch estimates are averaged (1,125 from fishermen surveys and 1,506 from the trawler observers – not far from each other), the number is 1,315 turtles caught by trawlers per year; half of them are estimated to end up dead.
Figure 4. Percentage of trawlers operating at the different depth ranges at night (black bars) and by day (grey bars), based on the fishermen questionnaire (n=16).

Strandings surveys
From 2008 to 2012, 1043 sea turtles were stranded on the Israeli shore: 631 Loggerheads (60%), 289 Greens (28%) and 123 strandings where the species was not recorded (12%). This is an average of 208.6 (±16.3) turtles each year: 126 (±11.6) Loggerheads, 58 (±11.8) Green and 25 (±18.3) unidentified species. The cause of stranding could be determined in 313 of the 1,043 cases, and 54% of those identified were attributed to the impact of fishing (Table 2). Within the fishing-attributed strandings, the dominant injuries were from longlines (30%) followed by gillnets (20%) and trawling (9%). The remaining 41% are spread in different combinations of these fishing methods and could not be assigned to a specific method. Some of the combinations include angling (e.g. small hooks and fishing line, Table 2). Angling is not further discussed in this study as this method is mainly recreational in Israel.

Based on the ISTRC data, an average of 209 turtles are stranded each year. Of these, approximately 54% (Table 2) were stranded due to fishery impacts (n=113), of which 38% (Figure 1) are due to trawling (n=42). Based on the by-catch mortality calculations above, 618 turtles die through trawlers annually but only 42 (7%) are found stranded, possibly indicating a ratio between the number of stranded turtles on the shore and the number of turtles that die at sea.

Mortality Rates
Comparing the analysis from the Israeli coast with data from other regions indicates that the highest annual stranding per year per coastline length occurs in Israel, 1.16 stranded turtles per kilometre per year, while the minimum (0.03) was found on Rhodes (Table 3). Because we cannot directly estimate mortality rates by fishing methods other than trawling, we used estimates from other regions to try to evaluate the annual turtle mortality in the region from the total estimated by-catch (nearly 3,000 turtles, Figure 2). For that, we have taken the median of different mortality estimates calculated from mortality rates reported for turtles in other regions of the world and applied them to the Israeli
Table 3. Turtle strandings per km of coastline in various locations according to available literature. No. = Number of years; Av. = Yearly average. *Calculated: not reported as such by the authors; **Combination of data sets or supported by the author (pers. comm.).

| Location                  | Strandings | Period     | No. | Km   | Av. | No./km/year | Reference                           |
|---------------------------|------------|------------|-----|------|-----|-------------|-------------------------------------|
| Rhodes                    | 209        | 1984-2011  | 28  | 220  | *7.5*| *0.03*      | Corsini-Foka et al. (2013)           |
| Eastern Spain             | 619        | 1993-2006  | 14  | 419  | *44.2*| *0.11*      | Tomas et al. (2008)                  |
| Western Gulf of Mexico    | 1795       | 1986-2000  | 5   | 1621**| 359  | 0.22        | Lewison et al. (2003)                |
| South Cyprus              | 2006-2007  | 2          | 27  | 25   | 0.37 |              | Casale & Margaritoulis (2010)        |
| Western Gulf of Mexico    | 3074       | 1986-2000  | 5   | 1621**| 614.8| 0.38        | Lewison et al. (2003)                |
| Turkey                    | 276        | 2005-2009  | 5   | ~130**| 55.2 | *0.42*      | Casale & Margaritoulis (2010)        |
| Northwestern Gulf of Mexico | 1047     | 1986-1989  | 4   | 620  | 261.8| 0.42        | Caillouet et al. (1991)              |
| Greece                    | 1719       | 1990-2005  | 15  | *114.6*| *0.44*|              | Koutsosedris et al. 2(006)           |
| South Cyprus              | 2006-2007  | 2          | 27  | 25   | 0.93 |              | Casale & Margaritoulis (2010)        |
| Israel                    | 1043       | 2008-2012  | 5   | 200  | *208.6*| 1.04        | present study                        |

fleet by-catch estimates (Table 4). The outcome is an estimated mortality rate of more than 1,500 turtles per year for Israel’s fishery fleet. Turtle mortality rate in Israel’s trawling fleet was found to be the highest among the Mediterranean fleets (Table 4).

**Discussion**

In this study, the small Israeli fishery was estimated to by-catch around 3,000 sea turtles in the Levant waters annually. Of these, approximately 7% end up stranded on shore. At least 47% of the trawling by-catches result in fatalities (618 dead turtles, Table 4). The contemporary sea turtle population in Israel is a relic of a much larger population (Kuller, 1999). Today, the main Mediterranean Loggerhead nesting concentrations are still in the eastern basin: Greece, Turkey and Cyprus, with only minor nesting aggregations in Israel as well as Egypt, Libya, Lebanon, Syria and Tunisia. Sporadic nests also occur in the western Mediterranean basin: Italy and Spain (Broderick, Glen, Godley & Hays, 2002; Casale & Margaritoulis, 2010; Laurent, Bradai, Hadoud, El Gomati & Hamza, 1999). Green Turtle nesting is even more localized, with most nesting occurring in the Levant: Syria, Turkey and Cyprus and only a small number of females nesting in Egypt, Israel and Lebanon (Broderick et al., 2002; Kasparek, Godley & Broderick, 2001; Rabia & Attum, 2014, Rees, Saad & Jony, 2008). Our findings indicate that the Israel fishing fleet poses a major threat to Mediterranean Sea turtle populations in the vulnerable stage of reproduction, when they are close to shore (Casale & Margaritoulis, 2010, p. 113–134; Hornell, 1935; Sella, 1981). Other studies show that the population is
Table 4. Turtle mortality estimates by Israel’s fishing methods; based on multiplying mortality rates in different regions by the estimated by-catch per method in Israel. Overall estimations are the median of all mortality estimates. Mortality in%; No. = No. of turtles per method.

| Method       | Location                  | Mortality | No. | Israel By-catch | Reference                  |
|--------------|----------------------------|-----------|-----|-----------------|----------------------------|
| Trawler      | Australia                  | 0-7       | 1.315 | 0-92            | Poiner et al. 1990         |
|              | Italy                      | 12.5      | 164.4 | Casale et al. 2004 |                            |
|              | Mediterranean Sea          | 16        | 210.4 | MAP-UNEP (1999)  |                            |
|              | Central Mediterr.         | 25        | 328.8 | Sala et al. 2011 |                            |
|              | Mediterranean Sea          | 28        | 368.2 | MAP-UNEP (1999)  |                            |
|              | Italy                      | 43        | 565.5 | Casale et al. 2004 |                            |
|              | Florida                    | 45.4      | 597.0 | MAP-UNEP 1999   |                            |
|              | Israel                     | 47.0      | 618.1 | Current research |                            |
|              | median                     | 26.5      | 348.5 |                 |                            |
| Gillnet      | Tunisia                    | 5.2       | 1.672 | 86.9            | Bradai 1993, Margaritoulis et al. 2003 |
|              | North Cyprus               | 10        | 167.2 | Godley et al. 1998 |                            |
|              | France                     | 53.7      | 897.9 | Laurent 1991    |                            |
|              | different countries        | 73.7      | 1.232.3 | Argano et al. 1992 |                            |
|              | Croatia                    | 74.7      | 1.249.0 | Lazar et al. 2006b |                            |
|              | Croatia                    | 83        | 1.387.8 | Lazar et al 1999 |                            |
|              | Corsica                    | 94.4      | 1.578.4 | Delaugerre 1987 |                            |
|              | median                     | 73.7      | 1.232.3 |                 |                            |
| Long-line    | Gulf of Mexico             | 0         | 129.6 | 0.0             | MAP-UNEP 1999              |
|              | Mediterranean Sea          | 0.4       | 0.5   | MAP-UNEP 1999   |                            |
|              | Gulf of Mexico             | 5.9       | 7.6   | MAP-UNEP 1999   |                            |
|              | Gulf of Mexico             | 7         | 9.1   | MAP-UNEP 1999   |                            |
|              | General                    | 10        | 13.0  | MAP-UNEP 1999   |                            |
|              | North Cyprus               | 10        | 13.0  | Godley et al. 1998 |                            |
|              | Mediterranean Sea          | 16.7      | 21.6  | MAP-UNEP 1999   |                            |
|              | Atlantic                   | 29.5      | 38.2  | Balazs & Pooley 1994 |                          |
|              | Western Mediterranean     | 25        | 32.4  | Balazs & Pooley 1994 |                      |
|              | Western Pacific and South China Sea | 42 | 54.4 | Balazs & Pooley 1994 | |
|              | median                     | 10.0      | 13.0  |                 |                            |
| Purse-seine  |                            | 0         | 0.0   | Chassot et al. 2009 |                          |
|              |                            | 2         | 67    | Amandè et al. 2011 |                        |
|              | median                     | 1.0       | 0.7   |                 |                            |
|              | Total                      | 3.183.6   | 1.594.4 |             |                            |

also threatened in its feeding grounds (Clusa et al., 2013) and migration routes (Godley et al., 2002; Rees et al., 2008; Stokes et al., 2015). Sea turtles are migratory species that pass through Israeli waters on route from their feeding grounds to specific nesting areas around the Mediterranean Sea. This makes a study of the impact of the Israeli fishery on sea turtles a most relevant issue for the whole Mediterranean Sea turtle population.
Importantly, the numbers we present probably underestimate the full scale of the problem, for the following reasons: only active legal vessels were taken into account, and both illegal fishing activity and potential fishing by permitted vessels that are considered non-active by the authorities but may still be operating could not be considered (Lindenstrauss, 2011). The average number of working days per trawler was given a cautious estimate of only 180 days per year, as reported during the 1990s (Edelist, Sonin, Golani, Rilov & Spanier, 2011), and the probability of caught turtles surviving was calculated based on the health condition of the turtle on board, without accounting for potential future mortality due to post-trauma (Domènech et al., 2014). Therefore, the actual impact is probably even higher than described.

Estimating the number of turtles caught each year by the Israeli fishery emerged from two different sources: a fishermen questionnaire, including all four fishing methods, and observers on board the trawlers, recording real-time data. The observers’ extrapolation estimated that the total number of turtles caught annually by trawlers is 1,506, while the estimate based on the questionnaire was 1,125. The difference between the two methods can be explained by several factors: the bias of memory-based questionnaires, and the fact that we did not take into account the seasonality in turtle distribution, different locations, haul depth, etc. Both estimates are of the same order of magnitude and are strongly correlated (94%) with the temporal trends of strandings. We therefore averaged the two estimates to an annual turtle trawling by-catch of 1,315.

Our by-catch data are similar to estimates from studies conducted in other parts of the Mediterranean Sea. Bottom trawlers catch a considerable number of turtles, with a wide range of mortality (Table 4) as a consequence of different haul durations that depend on several parameters (fishing area, target species etc.). Approximately 4,300 turtles were estimated to be captured annually by trawlers in the western part of the northern Adriatic Sea, whereas in the eastern part the catch rate was 15 times higher. In Tunisia the estimation is 5,500 captures (Casale et al., 2007).

The turtle catch rate of bottom trawling in Israel was 0.015 turtles per hour. This value is similar to that in Italy (Casale et al., 2007) and Greece, both with an estimated rate of 0.018 per hour (Panagopoulos, Sofouli, Teneketzis & Margaritoulis, 2003). In Australia, the rate varies between 0.0011 in the north (Poiner & Harris, 1996), 0.0029 in the east (Robins, 1995) and 0.015 in Australia’s northern prawn fishery (Poiner, Buckworth & Harris, 1990).

Turtles caught by trawlers can be found alive, dead or in a comatose state when brought on deck. Comatose turtles that are treated as dead (i.e. thrown into the sea) will die. By contrast, if they are treated with resuscitation techniques, they can often survive (Norton, 2005). Sea turtle mortality by trawling is due both to the physical stress exerted on the animal by the heavy weight of the catch inside the net, and to the inevitable apnoea a turtle caught in the net suffers because the net is kept submerged for several hours (Alessandro & Antonello, 2010; MAP-UNEP, 1999). It was previously reported that the major cause of sea turtle mortality is indeed drowning, which can be caused by trawling but also by nets and longlines (Crowder, Hopkins-Murphy & Royle, 1995). Most carcasses, however, show no evidence of the cause of death (Hart et al., 2006; Sis & Landry, 1992). We therefore infer that most of the stranded turtles whose cause of injury was classified as unknown died as a result of drowning. The fishery impact is probably much higher than can be accurately determined. Haul duration has a crucial effect on turtle mortality rate. In Australia’s northern prawn fishery, there was no mortality recorded in trawls of less than 90 min, 5% mortality in trawls of 165 min, and 7% in trawls of 180 min (Poiner et al., 1990), demonstrating that longer hauling greatly increases mortality rates (Nada & Casale, 2011). Water temperature also plays a role.
The metabolic rate of reptiles exponentially increases with environmental temperature (Newell, 1966). Colder sea surface temperatures may prolong the period before drowning occurs in air-breathing poikilotherms (Hart et al., 2006), and warmer waters can shorten it. In the eastern Mediterranean Sea, surface water temperatures show high seasonal variations and range from ~16°C during winter to 28°C in summer (Herut & Galil, 2000). Therefore, the high temperature in summer combined with the long haul duration may decrease survival rate. This may explain the high mortality rates in Israel compared to most other regions. Turtle mortality rate by trawling varies (Table 4) from 0% in certain parts of Australia (Poiner et al., 1990) to 45% in Florida (MAP-UNEP, 1999). We report that 47% of turtles caught in a standard haul time of 3.5–5.75 h die during the haul. The mortality rate of Israel’s trawling fleet is the highest in the Mediterranean. Furthermore, 45% of all fishermen we surveyed reported that they immediately throw a caught turtle back into the sea, which considerably reduces its survival chances (MAP-UNEP, 1999) because turtles can suffer post-trauma from the catch, which may lead to death a few weeks later (Casale et al., 2007; Domènech et al., 2014). We conclude that the 47% mortality rate caused by trawling in our region is an underestimate: the real number is higher.

Our study found that the gillnets and trawling fleets are the major threats to marine turtles in our region, with approximately 1,700 and 1,300 animals caught per year, respectively, but the by-catch per vessel is higher for trawler (48.9 turtles) than gillnet (20.9) vessels (Figure 2). The mortality rate from gillnets was not directly addressed in our study, but MAP-UNEP (1999) found that sea turtle mortality caused by this method in the Mediterranean varies according to water depth and net type from 5.2% in Tunisia for trammel nets, followed by France, 53.7%, Croatia, 83%, and Corsica with a staggering rate of 94.4% (Table 4). These authors concluded that gill nets are a very dangerous item of fishing gear.

Based on the fishermen questionnaires, the longline method forms a small percentage of the total impact (4% of total by-catch). Nevertheless, we found it to be the most common cause (30%) of fishery fatalities among stranded turtles arriving at the ISTRC (Table 2). Turtles held underwater by gillnets, longlines and trawlers have a lower chance of surviving (drowning is an “immediate” process), and thus rarely arrive at the rescue centre on time. Nevertheless, these results point to the paradox of the greater research effort on longlines versus trawling (Wallace et al., 2010).

Purse-seines constitute relatively the lowest threat to the sea turtle population by the Israeli fishery (2% of the total by-catch, Figure 2). This method is based on netting an observed catch (schooling fish) immediately when spotted, and the gear is not set for long hours in the water. As a result, even if a sea turtle is caught, it is immediately released, considerably reducing the risks of entanglement and drowning. A study on the European purse-seine tuna fishery in the Atlantic Ocean revealed that only 2% of the turtles end up dead (Amandè et al., 2011), and no mortality was reported by the French purse-seine fishery of the eastern Atlantic (Chassot, Amandè & Chavance, 2009) (Table 4).

By-catch Spatiotemporal Patterns
Fishermen indicated that most of the turtles are caught at depths shallower than 50 m. More than 70% are caught within a narrower range of 0-20 m. This finding is in agreement with current literature (Alessandro & Antonello, 2010; Casale & Margaritoulis, p. 15–28, 2010; Casale et al., 2007; Polovina, Howell, Parker & Balazs, 2003). As reported in these studies, the reason is that turtles spend most of their time at less than 60 m depth and dive no deeper than 100 m. Therefore, proximity to the shoreline increases
the chances of an encounter with fishing activity. Furthermore, 75% of the trawl fishermen indicated that most turtles are caught at night. Today, because trawling for shrimps is more fuel efficient than trawling for fish, almost all Israeli vessels target *Marsupenaeus japonicus* in the shallows (15-40 m) and at night (80 out of 114 shallow hauls were nocturnal) (Edelist et al., 2011), when turtles are abundant. The nesting season between May and July was reported as the period when most turtles visited the Israeli shore a century ago: “large numbers of the edible or Green Turtle frequent the coast of the northern district during the hot season” (Hornell, 1935), and this was later described again by Sella (1981) for the period between the First and Second World Wars: during April to July, at the height of the season, some 600 specimens were caught per day. Although today the deliberate catching of turtles is illegal, fishermen reported an increase of turtle by-catch during this period, meaning that turtles have been caught during their reproduction season for a century.

**Regional Perspective**

From a global perspective, a recent review of the worldwide patterns of marine turtle by-catch indicated that in the Mediterranean Sea the by-catch per unit effort (BPUE) and fishing effort by trawlers and longlines were among the highest in the world (Wallace et al., 2010). When regions within the Mediterranean are compared based on their mortality density per length of coastline (number of strandings per km), the highest rates are found on the Israeli coast (Table 3), with more than one turtle stranding per kilometre a year.

A possible explanation for the high number of turtles in Israeli waters is their attraction to feeding grounds in the Levant (Clusa et al., 2013) and to the preferred nesting grounds in the area (Casale & Margaritoulis, 2010; Kasparek et al., 2001), or that the region is part of the major migration routes of the Mediterranean turtles.

The high number of strandings may also reflect regional oceanographic patterns, i.e., winds and currents (Rosentraub & Brenner, 2007) that carry and accumulate the floating carcasses from the entire eastern basin and North Africa coasts and strand them on the south-eastern Levant shores. The Egyptian Mediterranean fishing fleet is situated upstream of the major longshore current of the Levant and is estimated to catch more than 7,100 turtles each year (Nada & Casale, 2011). Therefore, turtles that were killed by neighbouring fishing fleets probably strand on Israel’s coastline as well.

Nevertheless, only a small fraction of the dead turtles (an annual average of 209 turtles) eventually ends up on the Israeli shore: at least 618 turtles die annually through the trawling industry alone, but we have found that only 7% of the strandings were attributable to trawling. The actual number is probably higher since many strandings show no sign of cause of death, making drowning a reasonable assumption. Hart et al. (2006) found that on average, the number of carcasses stranded on ocean-facing beaches may represent, at best, approximately 20% of the total number of carcasses available at sea.

The very high number of almost 3,000 sea turtles encountered by the fishing industry threatens the sea turtle population in the region. Although some cases may represent recaptures (Casale & Freggi, 2005), the by-catch rate is staggering considering the small nesting population of approximately 100 Loggerhead nesting females and 10 Green Turtle nesting females in Israel (Casale & Margaritoulis, 2010). Still puzzling is the fact that the small Green Turtle population, which suffers a lot from a very high mortality (at least 28% of all strandings in Israel), has not gone regionally extinct by now. Regardless of the reasons, it is clear that intense intentional fishing of turtles in the early 20th century, followed by the considerable unintentional by-catch by the current fishing fleet close to shore during the breeding season, has brought the sea turtle populations nesting
Zoology in the Middle East

on the south-eastern shores of the Levant to the brink of extinction. As these threats are continuous, the chances of a meaningful population recovery are minimal, even with the effective conservation of nests and the treatment of stranding turtles such as carried out by ISTRC of the Israel Nature and Parks Authority over the past two decades. Nevertheless, the carrying capacity of the Levant coasts as a major turtle rookery can still be high considering that the population flourished in the past, so long as mitigation of the fishery impact can be enforced.

Recommendations to Mitigate Turtle By-catch

The high sea turtle by-catch by the Israeli fishery industry indicates the need to take urgent measures to regulate it. One very effective method is to establish large Marine Protected Areas (MPAs) with a total ban on fishing (Lotze, Coll, Magera, Ward-Paige & Airoldi, 2011). We recommend the establishment of marine reserves in front of beaches with a high sea turtle activity, using sea turtles as flagship species. We also suggest banning all fishing activity during the breeding season, when female sea turtles come ashore and the chances for encounter are much higher. This will be beneficial for conservation of the whole marine environment since the summer is also the breeding season for many fish species in the area (Tsikliras, Antonopoulou & Stergiou, 2010). We recommend limiting fishing grounds to a minimum bottom depth of 50 m because Loggerhead and Green Turtles mostly stay in areas shallower than 50 m when not migrating through the open sea (MAP-UNEP, 1999) and because fishermen indicated this as the depth range where turtles are mainly caught. Further, we recommend training fishermen on how to perform resuscitation techniques (Domènech et al., 2014) which would then be followed by transferring the turtles to the rescue centre. This would increase their survival rate after being caught in the nets. Similar recommendations have been made in Spain by Domènech et al. (2014).

Because of the high trawler by-catch and mortality rate, we recommend restricting this small (23 active trawlers) but deadly fleet, first of all by reducing the number of boats, by monitoring their activity, and by applying the use of Turtle Exclusion Devices (TEDs) (escape hatches that can be inserted into existing trawler nets) as recommended by many other researchers (Crowder et al., 1994; Crowder et al., 1995; Henwood et al., 1992; Zeeberg et al., 2006) and by the U.S. National Academy of Science panel (National Research Council, 1990). In South Carolina, TEDs reduced strandings by about 44% (Crowder et al., 1995) and by 67% in shrimp trawler-related mortalities in the wider Caribbean, with a reduction estimate of 97% if all areas would apply the TEDs (Henwood et al., 1992). In an experiment conducted in the Adriatic Sea (Mediterranean) by Sala et al. (2011), TEDs reduced the total by-catch without significantly reducing the commercial catch. These devices can reduce debris and by-catch in the trawl, making commercial fishermen interested in testing them for their potential to reduce damage to fish and speed up sorting time on deck (Sala et al., 2011). In addition, we recommend limiting night fishing by trawlers and reducing hauling durations to less than 120 minutes.

Gillnets are responsible for approximately 56% of turtle by-catch in Israel. On top of applying the restrictions mentioned above, trials and research are needed in order to identify methods to reduce sea turtle catch by gillnets without compromising economic viability. Increasing gear visibility to turtles through illumination and line materials (Gilman et al., 2010) is one available option, but it should be examined with caution because recent behavioural experiments indicate that light sticks used in many longline fisheries actually attract sea turtles (Alessandro & Antonello, 2010). More options include reducing net vertical height; increasing tiedown length or eliminating tiedowns;
incorporating shark-shaped silhouettes; and modifying float characteristics, the number of floats or eliminating floats (Gilman et al., 2010). Although by-catch by the longline method in Israel is low, it should not be disregarded. It is recommended to use lines made of biologically degradable materials. Another suggestion is to use circle-shaped hooks, with larger dimensions, that are less likely to be swallowed by turtles (Casale et al., 2007).

The fourth fishing method – purse-seine – seems to have a minimal if any impact on turtles, and therefore we do not recommend regulating it at present.

To summarise, fishing in Israel is a major threat to sea turtles not only locally but at a regional level. Therefore, significant restraints have to be applied on the industry in order to prevent the turtle population from going extinct. Protecting nests and rescuing injured turtles are insufficient for recovering or even sustaining the tiny remaining population.

Acknowledgements
We are greatly indebted to all the fishermen, Israel National Nature and Parks Authority workers and volunteers, and a special thanks to A. Fridman, G. Yahel, S. Eyal, H. Yoeli and the anonymous referees for helpful comments on the manuscript.

Funding
This work was funded by Israel National Nature and Parks Authority and School of Marine Sciences, Ruppin Academic Center (Michmoret, Israel).

Disclosure Statement
No potential conflict of interest was reported by the authors.

Supplementary Material
The Supplementary Annex 1 is available via the “Supplementary” tab on the articles online page (http://dx.doi.org/10.1080/09397140.2015.1101906).

References
Alessandro, L., & Antonello, S. (2010): An overview of loggerhead sea turtle (Caretta caretta) by-catch and technical mitigation measures in the Mediterranean Sea. Reviews in Fish Biology and Fisheries, 20, 141–161.
Amandè, M. J., Ariz, J., Chassot, E., de Molina, A. D., Gaertner, D., Murua, H., Pianet, R., Ruiz, J., Chavance, P. (2011): By-catch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003–2007 period. Aquatic Living Resources, 23, 353–362.
Balazs G. H., & Pooley S. G. (1994): Research plan to assess marine turtle hooking mortality. Results of an expert workshop held in Honolulu, Hawaii, November 16-18, 1993.
Bradburn, N. M., Sudman, S., & Wansink, B. (2004): Asking Questions: The Definitive Guide to Questionnaire Design -- For Market Research, Political Polls, and Social and Health Questionnaires. San Francisco: Jossey-Bass. A Wiley imprint.
Broderick, A. C., Glen, F., Godley, B. J., & Hays, G. C. (2002): Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. Oryx, 36, 227–235.
Caillouet, C. W. (Jr.), Duronslet, M. J., Landry, A. M. (Jr.), Reever, D. B., Shaver, D. J., Stanley, K. M., Heinly, R. W., & Stabenau, E. K. (1991): Sea turtle strandings and shrimp fishing effort in the northwestern Gulf of Mexico, 1986-89. Fishery Bulletin (U.S. Department of Commerce), 89, 712–718.
Camiñas, J. A., Báez, J., Valeiras, X., & Real, R. (2006): Differential loggerhead by-catch and direct mortality due to surface longlines according to boat strata and gear type. *Scientia Marina, 70*, 661–665.

Carreras, C., Cardona, L., & Aguilar, A. (2004): Incidental catch of the loggerhead turtle *Caretta caretta* off the Balearic Islands (western Mediterranean). *Biological Conservation, 117*, 321–329.

Casale, P. (2011): Sea turtle by-catch in the Mediterranean. *Fish and Fisheries, 12*, 299–316.

Casale, P., Cattarino, L., Freggi, D., Rocco, M., & Argano, R. (2007): Incidental catch of marine turtles by Italian trawlers and longliners in the central Mediterranean. *Aquatic Conservation: Marine and Freshwater Ecosystems, 17*, 686–701.

Casale, P., & Freggi, D. (2005): Interaction of the static net fishery with loggerhead sea turtles in the Mediterranean: insights from mark-recapture data. *The Herpetological Journal, 15*, 201–203.

Casale, P., & Margaritoulis, D. (Eds): (2010): *Sea turtles in the Mediterranean: Distribution, threats and conservation priorities*. Gland (Switzerland): IUCN/SSC Marine Turtle Specialist Group.

Casale, P., Laurent, L., & Metrio, G. de. (2004): Incidental capture of marine turtles by the Italian trawl fishery in the north Adriatic Sea. *Biological Conservation, 119*, 287–295.

Chassot, E., Amandè, M., & Chavance, P. (2009): Some preliminary results on tuna discards and by-catch in the French purse seine fishery of the eastern Atlantic Ocean. *Collective Volume of Scientific Papers, 64*, 1054–1067.

Clusa, M., Carreras, C., Pascual, M., Stephen J. Gaughran, S. J., Piovano, S., Giacomia, C., Fernández, G., Levy, Y., Tomás, J., Raga, J. A., Maffucci, F., Hochscheid, S., Aguilar, A., Cardona, L. (2013): Fine-scale distribution of juvenile Atlantic and Mediterranean loggerhead turtles (*Caretta caretta*) in the Mediterranean Sea. *Marine Biology, 161*, 509–519.

Corsini-Foka, M., Kondylatos, G., & Santorinios, E. (2013): Increase of sea turtles stranding records in Rhodes Island (eastern Mediterranean Sea): update of a long-term survey. *Journal of the Marine Biological Association of the United Kingdom, 93*, 1991–2002.

Crowder, L. B., Crouse, D. T., Heppell, S. S., & Martin, T. H. (1994): Predicting the impact of turtle excluder devices on loggerhead sea turtle populations. *Ecological Applications, 4*, 437–445.

Crowder, L., Hopkins-Murphy, S., & Royle, J. (1995): Effects of turtle excluder devices (TEDs) on loggerhead sea turtle strandings with implications for conservation. *Copeia, 4*, 773–779.

Domènech, F., Álvarez de Quevedo, I., Merchán, M., Revuelta, O., Vélez-Rubio, G., Bitón, S., Cardona, L., Tomás, J. (2014): Incidental catch of marine turtles by Spanish bottom trawlers in the western Mediterranean. *Aquatic Conservation: Marine and Freshwater Ecosystems*, doi: 10.1002/aqc.2463.

Edelist, D., Sonin, O., Golani, D., Rilov, G., & Spanier, E. (2011): Spatiotemporal patterns of catch and discards of the Israeli Mediterranean trawl fishery in the early 1990s: ecological and conservation perspectives. *Scientia Marina, 75*, 641–652.

Gilman, E., Gearhart, J., Price, B., Eckert, S., Milliken, H., Wang, J., … Ishizaki, A. (2010): Mitigating sea turtle by-catch in coastal passive net fisheries. *Fish and Fisheries, 11*, 57–88.

Godley, B. J., Gürçü, A. C., Broderick, A. C., Furness, R. W., & Solomon, S. E. (1998): Interaction between marine turtles and artisanal fisheries in the eastern Mediterranean: a probable cause for concern? *Zoology in the Middle East, 16*, 49–64.

Godley, B. J., Richardson, S., Broderick, A. C., Coyne, M. S., Glen, F., & Hays, G. C. (2002): Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. *Ecography, 25*, 352–362.

Gruvel, A. (1931): *Les Etats de Syrie. Richesses marines et fluviales. Exploitation actueller, Avenir*. Paris: Société des Editions Géographiques, Maritimes et Coloniales.

Hart, K. M., Mooreside, P., & Crowder, L. B. (2006): Interpreting the spatio-temporal patterns of sea turtle strandings: Going with the flow. *Biological Conservation, 129*, 283–290.

Henwood, T., Stuntz, W., & Thompson, N. (1992): Evaluation of US Turtle Protective Measures Under Existing TED Regulations, Including Estimates of Shrimp Trawler Related Turtle Mortality in the Wider Caribbean, NOAA Technical Memorandum NMFS-SEFSC-303, 1–14.
Herut, B., & Galil, B. (2000): The coast of Israel, southeast Mediterranean. pp. 253–265. In: C. Sheppard (Ed.), Seas at the millennium: an environmental evaluation: Vol. I. Pergamon. London: Elsevier.

Hornell, J. (1935): Report on the fisheries of Palestine. London, S.W.I., The goverment of Palestine by the Crown Agents for the Colonies, 65.

Jackson, J. B. C., Kirby, M. X., & Berger, W. H. (2001): Historical overfishing and the recent collapse of coastal ecosystems. Science 293 (5530), 629–637.

Jribi, I., Bradai, M., & Bouain, A. (2007): Impact of trawl fishery on marine turtles in the Gulf of Gabes, Tunisia. The Herpetological Journal 17, 110–114.

Kasparek, M., Godley, B. J., & Broderick, A. C. (2001): Nesting of the Green Turtle, Chelonia mydas, in the Mediterranean: a review of status and conservation needs. Zoology in the Middle East, 24, 45–74.

Koutsodedris, A., Papadopoulou, S., & Margaritoulis, D. (2006): Distribution of sea turtles (Caretta caretta and Chelonia mydas) along the Greek coasts based on 15 years strandings (1990–2005). p. 48. In: Book of Abstracts of the Tenth International Congress on the Zoogeography and Ecology of Greece and Adjacent Regions. Hellenic Zoological Society, Patra, Greece. Athens.

Kuller, Z. (1999): Current status and conservation of marine turtles on the Mediterranean coast of Israel. Marine Turtle Newsletter, 86, 3–5.

Laurent, L., Bradai, M. N., Hadoud, D. H., El Gomati, H. M., & Hamza, A. A. (1999): Marine Turtle Nesting Activity Assessment on Libyan Coasts. Phase 3: Survey of the coast to the west of Misratah. Tunis: United Nations Environment Programme, Mediterranean Action Plan Regional Activity Centre for Specially Protected Areas.

Lewison, R. L., Crowder, L. B., & Shaver, D. J. (2003): The impact of Turtle Excluder Devices and fisheries closures on Loggerhead and Kemp’s Ridley strandings in the Western Gulf of Mexico. Conservation Biology, 17, 1089–1097.

Lindenstrauss, M. (2011): The State of Israel Comptroller Report, 1097–1129.

Lotze, H. K., Coll, M., Magera, A. M., Ward-Paige, C., & Airoldi, L. (2011): Recovery of marine animal populations and ecosystems. Trends in Ecology & Evolution, 26, 595–605.

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M. N., Caminas, J. A., & Casale, P. (2003): Loggerhead turtles in the Mediterranean Sea: present knowledge and conservation perspectives. pp. 175–198. In: Bolten, A, & Witherington, B. E. (Eds.), Loggerhead sea turtles. Washington (D.C.): Smithsonian Books.

MAP-UNEP (1999): Interaction of marine turtles with fisheries in the Mediterranean. Prepared by G. Gerosa & P. Casale for the Mediterranean Action Plan (MAP). Tunis Cedex: Regional Activity Centre For Specially Protected Areas.

Moore, J. E., Cox, T. M., Lewison, R. L., Read, A. J., Bjorkland, R., McDonald, S. L., … Kiszka, J. (2010): Interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. Biological Conservation, 143, 795–805.

Nada, M., & Casale, P. (2011): Sea turtle by-catch and consumption in Egypt threatens Mediterranean turtle populations. Oryx, 45, 143–149.

National Research Council (1990): Sea turtle mortality associated with human activities. pp. 74–117. In: Committee on Sea Turtle conservation (Ed.), Decline of the sea turtles: Causes and prevention: Washington, D.C.: The National Academies Press.

Newell, R. C. (1966): Effect of temperature on the metabolism of poikilothersms. Nature, 212, 426–428.

Norton, T. (2005): Chelonian emergency and critical care. Seminars in Avian and Exotic Pet Medicine, 14, 106–130.

Panagopoulos, D., Sofouli, E., Teneketzis, K., & Margaritoulis, D. (2003): Stranding data as an indicator of fisheries induced mortality of sea turtles in Greece. pp. 202–206. In: D. Margaritoulis & A. Demetropoulos (Eds.), Proceedings of the first Mediterranean conference on marine turtles. Nicosia.

Poineer, I., Buckworth, R., & Harris, A. (1990): Incidental capture and mortality of sea turtles in Australia’s northern Prawn Fishery. Marine and Freshwater Research, 41, 97.

Poineer, I., & Harris, A. (1996): Incidental capture, direct mortality and delayed mortality of sea turtles in Australia’s Northern Prawn Fishery. Marine Biology, 125, 813–825.
Polovina, J., Howell, E., Parker, D., & Balazs, G. (2003): Dive-depth distribution of loggerhead (Carretta carretta) and olive ridley (Lepidochelys olivacea) sea turtles in the Central North Pacific: Might deep longline sets catch fewer turtles? *Fishery Bulletin, 101*, 189–193.

Rabia, B. & Attum, O. (2014): Distribution and status of sea turtle nesting and mortality along the North Sinai coast, Egypt (Reptilia: Cheloniidae): *Zoology in the Middle East, 61*, 26–31.

Rees, A., Saad, A., & Jony, M. (2008): Discovery of a regionally important green turtle Chelonia mydas rookery in Syria. *Oryx, 42*, 456–459.

Robins, J. B. (1995): Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia. *Biological Conservation, 74*, 157–167.

Rosentraub, Z., & Brenner, S. (2007): Circulation over the southeastern continental shelf and slope of the Mediterranean Sea: Direct current measurements, winds, and numerical model simulations. *Journal of Geophysical Research: Oceans, 112*, C11001.

Sala, A., Lucchetti, A., & Affronte, M. (2011): Effects of Turtle Excluder Devices on by-catch and discard reduction in the demersal fisheries of Mediterranean Sea. *Aquatic Living Resources, 24*, 183–192.

Sella, I. (1981): Sea Turtles in the Eastern Mediterranean and Northern Red Sea. pp. 417–423. In: K. A. Bjorndal (Ed.), *Biology and conservation of sea turtles. Proceeding of the world conference on sea turtle conservation. Washington, D.C. 26-30 November 1979*.

Shapiro, J. (2008, 2009, 2010): *The fisheries and aquaculture of Israel 2007, 2009, 2010*. Tiberias: The State of Israel, Ministry of Agriculture & Rural Development, Department of Fisheries and Aquaculture.

Sis, R., & Landry, A. (1992): Postmortem changes in the turtle. pp. 17–19. In: *Proceedings of the 23rd Annual International Association for Aquatic Animal Medicine (IAAAM)*. Hong Kong. San Leandro, California: IAAAM.

Stokes, K. L., Broderick, A. C., Canbolat, A. F., Candan, O., Fuller, W. J., Glen, F., Levy, Y., Rees, A. F., Rilov, G., Snape, R. T., Stott, I., Tchernov, D., & Godley, B. J. (2015): Migratory corridors and foraging hotspots: critical habitats identified for Mediterranean green turtles. *Diversity and Distributions, 21*, 665–674.

Tomás, J., Gozalbes, P., Raga, J., & Godley, B. (2008): Bycatch of loggerhead sea turtles: insights from 14 years of stranding data. *Endangered Species Research, 5*, 161–169.

Tsikliras, A. C., Antonopoulou, E., & Stergiou, K. I. (2010): Spawning period of Mediterranean marine fishes. *Reviews in Fish Biology and Fisheries, 20*, 499–538.

Wallace, B. P., Lewison, R. L., McDonald, S. L., McDonald, R. K., Kot, C. Y., Kelez, S., Bjorkland, R. K., Finkbeiner, E. M., Helmbrecht, S., Crowder, L. B. (2010): Global patterns of marine turtle by-catch. *Conservation Letters, 3*, 131–142.

Zeeberg, J., Corten, A., & de Graaf, E. (2006): By-catch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. *Fisheries Research, 78*, 186–195.