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Estimates of sea turtle mortality from poaching and bycatch in Bahía Magdalena, Baja California Sur, Mexico

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ABSTRACT

Bahia Magdalena on the Pacific coast of Baja California Sur, Mexico, is an important feeding and nursery ground for black turtles *Chelonia mydas*, loggerhead turtles *Caretta caretta*, olive ridley turtles *Lepidochelys olivacea*, and hawksbill turtles *Eretmochelys imbricata*. Despite international and national protection, sea turtles continue to be caught incidentally and hunted for consumption in large numbers. This study examines the mortality of sea turtles in Bahia Magdalena, focusing on (1) species distribution and number of carcasses found, (2) causes of death, (3) size frequency distribution and % juveniles in the catch, and (4) changes in average size over the past years. A total of 1945 turtle carcasses were found from April 2000 to July 2003 along beaches and in towns of the region with loggerhead (44.1%) and black turtles (36.9%) being the dominant species. Slaughter for human consumption was the primary cause of death of carcasses found in towns (95–100%), while carcasses on beaches mostly died of unknown causes (76–100%). Circumstantial evidence suggests however, that incidental bycatch was the main mortality cause on beaches. Black turtles suffered the highest consumption mortality overall (91%), followed by olive ridley (84%), hawksbill (83%) and loggerhead turtles (63%). Over 90% of all turtles found were juveniles or subadults. Carapace length of black turtles declined consistently over the sampling period, while that of loggerhead turtles increased. Our results strongly suggest that turtles are being taken at high and unsustainable rates; this may partially explain why the populations have not recovered despite widespread protection on nesting beaches.

1. Introduction

The waters of the Baja California peninsula provide important nursery and feeding habitat for five of the world's seven sea turtle species (e.g. Cliffton et al., 1982; Márquez, 1990; Gardner and Nichols, 2001; Koch et al., 2002; Nichols, 2003; Seminoff et al., 2003). Hawksbill *Eretmochelys imbricata* and leatherback *Dermochelys coriacea* turtles are listed under the IUCN Global Red List as critically endangered, while loggerhead *Caretta caretta*, olive ridley *Lepidochelys olivacea* and East Pacific green or black turtles *Chelonia mydas* are listed as endangered (IUCN, 2004).

Intense exploitation, especially from the 1950s through the 1970s led to drastic population declines of black, olive ridley

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and hawksbill turtles in the region, with Mexico contributing over 50% of the world's sea turtle catch during that time period (Márquez and Doi, 1973; Márquez et al., 1982b; Márquez, 1990). Leatherback and loggerhead turtles were hunted to a lesser degree, but have been impacted by high rates of incidental bycatch in driftnet and long line fisheries (Spotila et al., 2000; Nichols, 2003; Peckham et al., in press). To protect the severely reduced populations, a complete ban on sea turtle catch and the use and trade of sea turtle products was established in México in 1990 (Aridjis, 1990; Diario Oficial de la Federación, 1990).

While nesting beach protection has been operating successfully for three decades at several important rookeries along the Pacific coast of Mexico (Márquez et al., 1996), protection of coastal foraging and developmental habitats lags substantially (Koch et al., 2002; Nichols, 2003; Seminoff et al., 2003). Sea turtle meat is still considered a delicacy in Northwestern Mexico and, as a consequence, illegal hunting on the coastal feeding grounds remains a major threat.

Bahía Magdalena is an important developmental area for sea turtles on the Pacific coast of Mexico. Large numbers of black, loggerhead and olive ridley turtles and few hawksbill turtles occur in and around the bay (Gardner and Nichols, 2001; Koch et al., 2002; Peckham and Nichols, 2002; Nichols, 2003). Bahía Magdalena is also the most important fishing ground for artisanal fisheries in the state of Baja California Sur (Carta Nacional Pesquera, 2004). Bottom set gillnets are the most commonly used fishing gear in the area and sea turtles are frequently caught both intentionally and incidentally resulting in high rates of fishing mortality (Gardner and Nichols, 2001; Koch et al., 2002; Nichols, 2003; Peckham et al., 2004).

Population recovery of all species may be impeded by both, illegal hunting and incidental by catch. Although it is extremely difficult to get reliable data on the illegal exploitation of protected species, even rough estimates of mortality numbers, causes of mortality and distribution of dead turtles in time and space, provide important data to inform the development of effective conservation strategies. Therefore, our objective was to monitor sea turtle mortality at Bahía Magdalena to determine the extent of the illegal exploitation in the region. Specifically we studied: (1) species distribution of dead turtles in the area; (2) principal causes of death; (3) minimum annual mortality rates for each species; (4) changes in size distribution of dead turtles during the study period; (5) prospects for recovery of the populations under current fishing pressure.

2. Methods

2.1. The study area

The Bahía Magdalena–Almejas coastal lagoon complex is located on the Pacific coast of Baja California Sur, Mexico, between 24°15′N 111°30′W and 25°20′N 112°15′W (Fig. 1). It is protected by three barrier islands (Magdalena, Margarita and Creciente), the principal opening to the Pacific is about 4 km wide and up to 40 m deep. Average depth in the bay is less than 15 m and large shallow water and intertidal areas are present (Alvarez-Borrego et al., 1975). Sea grass and red algae are abundant and extensive mangrove channels are located in the northern part of the bay.

2.2. Sampling

We monitored sea turtle mortality in Bahía Magdalena in six towns and their dumpsites and on two beaches with a total length of 60 km (Fig. 1) every 2–4 months from April 2000 to July 2003. Each carcass found was identified, measured from the anterior notch to the posterior part of the carapace with a caliper (straight carapace length or SCL) and marked with spray paint or collected to avoid recounting (Gardner and Nichols, 2001). We determined cause of death when possible, and categorized carcasses as follows: (1) *consumed:* carapaces found on dump sites, charred or with harpoon holes present; (2) *bycatch mortality:* carcasses entangled in fishing gear or with marks of fishing gear; (3) *unknown mortality* : carcasses where no obvious cause of mortality was observable. Note that evidence of trawl and gillnet interactions on turtle carcasses is rare. Incidentally captured turtles are also known to be consumed, and recorded here as such. As a result our *bycatch mortality* category severely underestimates bycatch related mortality. We did not find turtles with fresh wounds from shark bites, fibropapilloma tumors or turtles that were emaciated (the latter is hard to detect in decaying carcasses that are bloated or already dried out).

2.3. Data analysis

We averaged the distribution of carcasses of each species over the sampling period at each location to see where the highest mortalities occurred. Total death count for each species gave a conservative mortality estimate per year, and we calculated the percentage of apparent mortality causes. We constructed size frequency distributions for each species and estimated the percentage of juveniles and adults. Size at maturity in females is close to average nesting size in several sea turtles (Limpus and Walter, 1980; Limpus, 1990, 1992; Limpus and Limpus, 2003) and we used values reported in the literature as an approximation (converted to SCL): black turtle 77 cm (Alvarado and Figueroa, 1990; Márquez, 1990); loggerhead 85 cm (Limpus and Limpus, 2003; Hatase et al., 2004); olive ridley 60 cm (Márquez, 1990; Miller, 1997); hawksbill turtle 75 cm (Márquez, 1990; Limpus, 1992).

For black, loggerhead and olive ridley turtles, we compared average size per year with data from 1995 (Nichols, 2003) and 1999 (Gardner and Nichols, 2001), that were collected at the same sites in Bahía Magdalena using the same protocol. Thus, differences found between years reflect population trends rather than sampling bias. Data were compared using 1-way analysis of variance, homogeneity of variance was tested with Hartley's F-max test at $p \leqslant 0.01$, using the approximation for unequal sample sizes suggested in Sokal and Rohlf (1995). Unplanned mean comparisons were done using Tukey's HSD test (Sokal and Rohlf, 1995). Data analysis was done with the statistical package SYSTAT 5.2 for the Macintosh (Wilkinson et al., 1992).

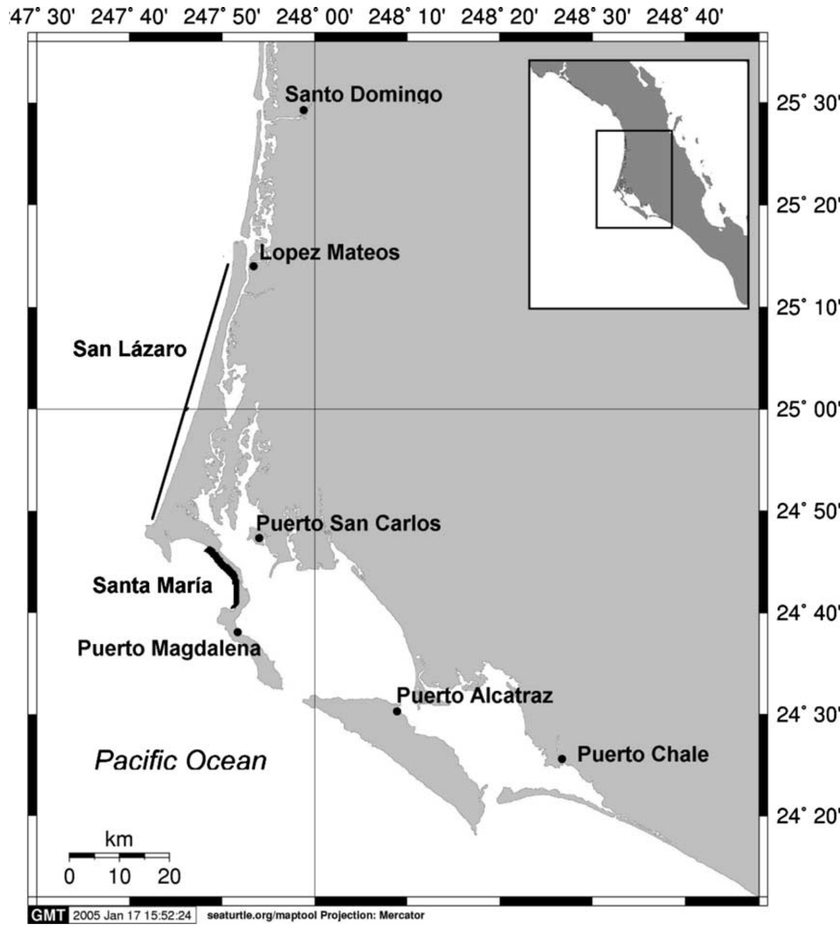

Fig. 1 – Map of the study area, Bahía Magdalena, with the census locations.

3. Results

Loggerhead and black turtles were the species most commonly encountered at all sites (Fig. 2). Loggerhead carcasses made up the greatest proportion on the Pacific beaches and in the northernmost towns (Lopez Mateos and Santo Domingo), whereas black turtle carcasses were dominant at all sampling sites inside Bahía Magdalena.

A total of 1945 dead turtles were found over the study period, with loggerheads being the most common species, followed by black, olive ridley, and hawksbill turtles (Table 1). The most abundant species found on beaches was the loggerhead followed by black and olive ridley turtles. In towns, the black turtle was the dominant species, followed by loggerhead and olive ridley turtles. Black turtles suffered the highest consumption mortality overall (91%), followed by olive ridley (84%), Hawksbill (83%) and loggerhead turtles (63%). *Consumption mortality* accounted for 95–100% in towns and dumps, but for only 0–24% of total mortality on beaches where *unknown mortality* was dominant (76–100%). *Bycatch mortality* accounted only for a very small number of turtles (<1%) and is not shown separately.

The size frequency histograms of all species show that most dead turtles were juveniles (Fig. 3). Highest percentage of juveniles was found in hawksbill turtles (average size 42.8 ± 7.8 cm SCL), followed by loggerhead (63.4 ± 8.8 cm SCL), black (55.9 ± 13.0 cm SCL) and olive ridley turtles (58.5 ± 5.8 cm SCL). No turtles smaller than 25 cm SCL were found. The average size of black and olive ridley turtles decreased significantly throughout the study period (black: 15% from 1995 to 2003, olive ridley: 6.5% from 2000 to 2003) while loggerhead turtles showed a significant increase of 14.7% during the same period (Table 2, Fig. 4). Tukey's post-hoc comparison resulted in two homogeneous groups for the black (1995–2000, and 2001–2003), olive ridley (2000–2002, 2001–2003) and loggerhead turtles (1995 and 1999, and 2000–2003), as shown by the letters in Fig. 4. The percentage of small juveniles (⩽45 cm) since 1995 increased in black turtles by a factor of about two, while it decreased in loggerhead turtles by more than 60%, with a more pronounced trend in loggerheads found on beaches (Fig. 5).

4. Discussion

The distribution of dead turtles in the Bahía Magdalena region reflects both their natural distribution in the area and also the predominant fishing grounds and culinary preferences of each coastal community. Loggerhead turtles are the most abundant species in the coastal Pacific but do not usually enter Magdalena Bay (Koch et al., 2002; Nichols, 2003; Peckham

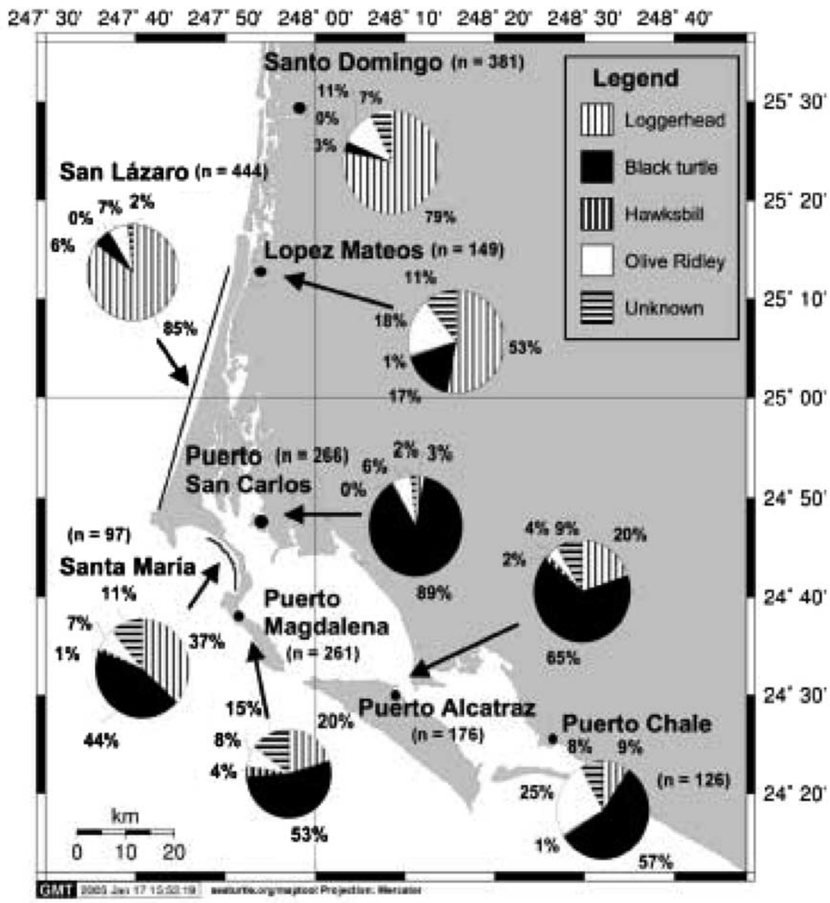

Fig. 2 – Distribution of dead sea turtles found throughout Bahía Magdalena from 2000 to 2003. Percentage mortality of each species at each location is given in the pie charts, total number of carcasses found at each location (*n*) is shown in parenthesis.

et al., in press). They consequently made up 85% (Fig. 2) of the carcasses encountered at Playa San Lazaro, an oceanic beach on the outside of Magdalena Bay, and in the two northernmost communities (Lopez Mateos and Santo Domingo), where people fish mostly in the Pacific. Black turtles were the dominant species found in communities inside the bay (Koch et al., 2002; Nichols, 2003) where people fish mostly inside the Bahía Magdalena lagoon complex and consequently catch more black turtles. Olive Ridley turtles are abundant in the coastal Pacific, but carcasses only accounted for a relatively small percentage and were fairly equally distributed at all sites. This probably reflects culinary preference for black turtles and loggerheads over olive ridleys. Too few hawksbill turtles were found to detect any pattern.

Our minimum mortality rate estimate (>600 turtles year^{-1}) is conservative. Total mortality on beaches could be up to 10 times higher than recorded, as stranding rates of turtles that have died offshore may only account for 7–13% of total mortality, with distance from shore, wind and current regime being the most important factors that influence stranding

Table 1 – Number of dead turtles found between April 2000 and July 2003 in the Bahía Magdalena region, including % values for consumption and other (unknown) mortality

Species	Total number found 2000–2003 (% total)	Mortality (%) Consumption/ unknown	Town		Beach	
			Number found year^{-1} Av. ± SD	Mortality (%) Consumption/ unknown	Number found year^{-1} Av. ± SD	Mortality (%) Consumption/ unknown
Loggerhead	858 (44.1%)	67/33	118 ± 144	100/0	103 ± 39	6/94
Black turtle	718 (37.0%)	91/9	155 ± 23	100/0	17 ± 10	24/76
Olive Ridley	201 (10.3%)	84/16	37 ± 23	100/0	12 ± 6	14/86
Hawksbill	19 (1.0%)	83/17	4 ± 5	95/5	<1	–
Unidentified	149 (7.6%)	77/22	28 ± 22	100/0	9 ± 4	11/89

Results were shown separately for town and beach samples.

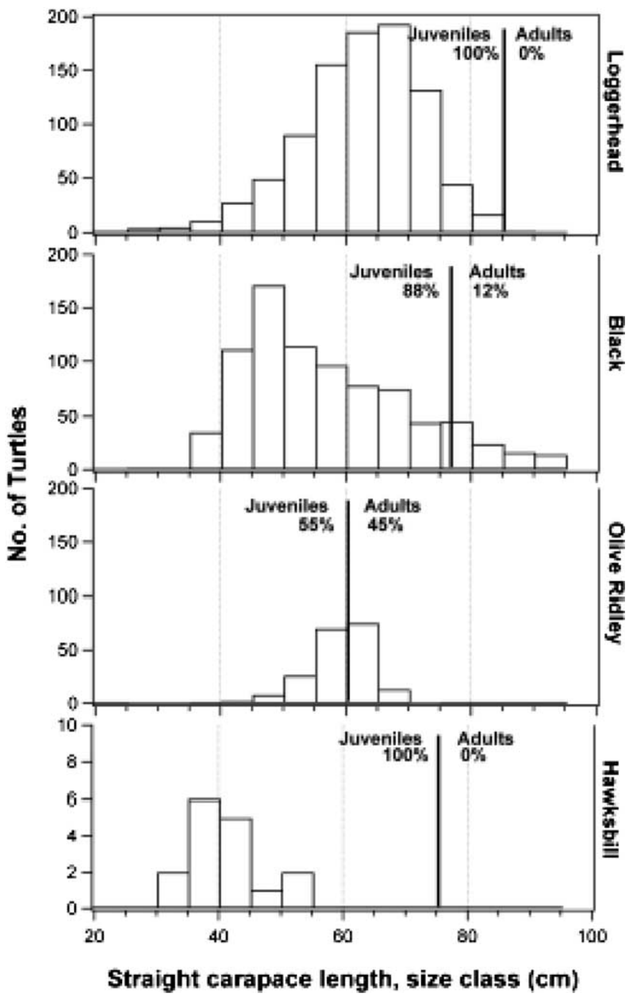

Fig. 3 – Size frequency distributions for loggerhead, black, olive ridley and hawksbill turtles found in Bahía Magdalena from 2000 to 2003. Black bars denote the approximate size at maturity (see Section 2), % juvenile and adult turtles are shown in each graph. Please note the different y-axis scale for the hawksbill turtle.

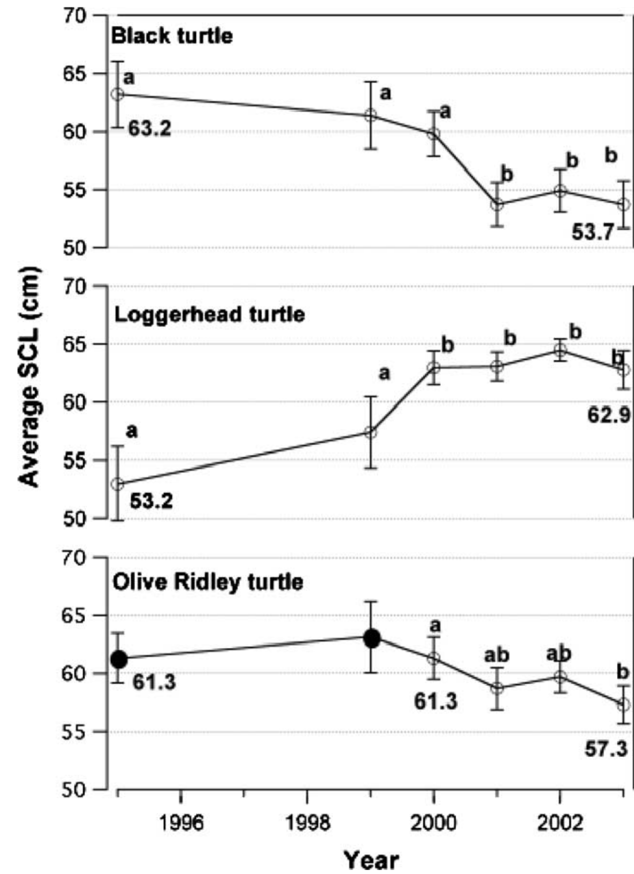

Fig. 4 – Average size (and SD) of loggerhead, black and olive ridley turtles found in the Bahía Magdalena region. Data from 1995 to 1999 were taken from Nichols (2003) and Gardner and Nichols (2001) (see Section 2). Numbers in the graph are average sizes, letters denote homogeneous groups defined by one-way ANOVA (Table 2) and Tukey's post-hoc comparison. The data for 1995 and 1999 for the Olive Ridley were excluded from the analysis because <10 turtles were found in these years.

(Epperly et al., 1996). Additionally, surveys were only conducted every 2–4 months, and beached carcasses may have been buried in the sand and/or eaten by coyotes, vultures and dogs (de la Toba, personal observation). Carcasses found in towns and dump sites also give only a conservative estimate; people may dump turtle remains in the desert, throw them in the water and turtles are exported from the region for black market trade. It is difficult to estimate the percentage of turtles that were not encountered during sampling, but it can be assumed to be considerable.

Table 2 – ANOVA table for the comparison of average size of Loggerhead and Black (1995–2003), and Olive Ridley (2000–2003) turtles

Effect	SS	DF	MS	*F*	*P*
Loggerhead (year)	6753.71	5	1350.74	15.41	<0.0001
Error	79165.36	903	87.67		
Black (year)	10509.99	5	2102.00	12.433	<0.0001
Error	138467.06	819	169.07		
Olive Ridley (year)	344.93	3	114.98	3.216	0.024
Error	6292.62	176	35.75		

The results for Tukey's post-hoc comparison are shown in Fig. 4. Data from 1995 to 1999 were taken from Nichols (2003) and Gardner and Nichols (2001) respectively (see Section 2).

When comparing our results with other estimates, it becomes clear that Bahía Magdalena (area: about 1200 km^2) is a mortality hot spot with a minimum rate of about 600 turtles year^{-1}. The high seas longline fishery in the North Pacific with a fishing effort of over 1.9 million hooks/day killed roughly 3000 loggerhead turtles per year in 2000 (Lewison et al., 2004). In the Western Pacific, the Queensland otter trawl fishery killed 53–360 turtles year^{-1} (Robins, 1995), the Australian longline fishery reported 402 turtles killed year^{-1} between 1997 and 2001 (Robins et al., 2002). The coastal set net fishery in Taiwan reported about 32 turtles year^{-1} from 1991 to 94 (Cheng and Chen, 1997). The Hawaiian longline fishery killed between 112 and 161 year^{-1} from 1994 to 99 (McCracken,

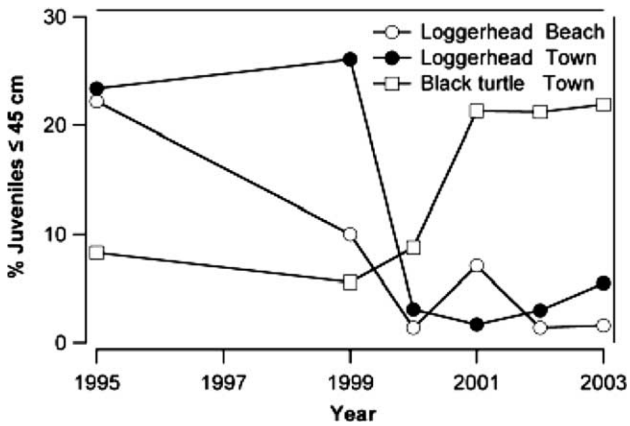

Fig. 5 – Percentage of small juveniles (⩽45 cm SCL) of loggerhead and black turtles. Loggerhead data for carcasses found on beaches and in towns are presented separately. Data from1995 to 1999 were taken from Nichols (2003) and Gardner and Nichols (2001) (see Section 2).

2000). Only Arauz (1996) reported exremtely high bycatch mortality of up to 60,000 sea turtles in Eastern Central Pacific shrimp fishery in 1993 (see NOAA, 2004 for more references).

While industrial longline, trawl and setnet fisheries are usually blamed as the main threats to sea turtle populations, mortality caused by artisanal fisheries may be much more important than previously thought. In Baja California, small scale coastal fisheries are causing mortality rates that exceed most numbers reported elsewhere. While it is difficult to extrapolate the data from only six fishing communities, mortality in the region could pose an important threat to the populations, especially when considering that there are about 150 fishing communities on the peninsula (Nichols, 2003), and that sea turtle meat is considered a delicacy throughout Northwestern Mexico. Nichols (2003) estimated a take of at least 7800 black turtles year^{-1} for consumption and suggests that in total over 30,000 turtles may die in Baja California each year. A similar situation has been reported only from Indonesia where over 30,000 green turtles are slaughtered annually for consumption (Dermawan, 2002) and from Nicaragua, where Miskito indians hunt aproximately 10,000 green turtles year^{-1} (Lagueux, 1998).

The fact that human consumption accounts for 63–91% of the total mortality reported for each species underlines that legal protection and law enforcement are not effective in stopping sea turtle consumption. The demand for sea turtle meat is high in coastal communities, in cities throughout Northwest Mexico, and even in the Southwestern US (Nichols, 2003). *Unknown mortality* accounts for almost all other deaths and is most prominent on beaches with 76–100%, but is most likely also related to fisheries. Most of the unknown mortality (>75%) on the beaches is registered during the halibut season from May to September that employs bottom set gillnets and there is a strong correlation between fishing effort and sea turtle mortality (Peckham and Nichols, 2002; Peckham, unpublished data). Interviews showed that fishermen may catch over 20 turtles (mainly loggerheads) in one single day during halibut season (Peckham, unpublished data). This highlights the necessity for the design of "turtle friendly" fishing gear, education campaigns and stricter fisheries regulations and law enforcement.

The size distributions show that the area around Bahía Magdalena is an important nursery ground for loggerhead, black, and hawksbill turtles. The large number of juveniles killed each year is alarming, as demographic models of loggerhead (Crouse et al., 1987; Crowder et al., 1994; Heppell et al., 2003a,b) and other sea turtles (Crouse, 1999) have shown that population persistence in sea turtles is sensitive to relatively small changes in survival of large juveniles. Thus the protection of juveniles on their coastal foraging grounds should be a conservation priority and the high fishing mortality of juveniles in the Bahía Magdalena region is of grave concern. Only for the olive ridley population the potential for population-level impacts is small, due to lower anthropogenic mortality (Table 1, see also Nichols, 2003; Peckham et al., in press), larger population size (Márquez, 2000), and higher growth and reproductive rates than the other species (Márquez et al., 1982a,b; NOAA, 2004).

The decline in carapace length of black turtles indicates that more recruits are arriving at the coastal nursery grounds. The doubling in the percentage of small juvenile black turtles (⩽45 cm) since 1995 (Fig. 5) confirms that, as well as data from the main nesting beaches in Mexico, which have shown positive population trends in the past years (Alvarado, pers. comm.). However, black market demand is greater for larger and more valuable animals and the observed trend could result in part from the high fishing pressure on large juveniles and adults. Therefore, the size trends need to be interpreted cautiously and more information is needed over a longer time period.

Our data and those of Gardner and Nichols (1999) and Nichols (2003) show that average size in loggerhead turtles has increased, while the percentage of juveniles ⩽45 cm has diminished considerably since 1995. This probably reflects the negative population trend on Japanese beaches between 1950 and 2000, where a 50–90% reduction in the number of nesting loggerhead turtles was reported (Kamezaki et al., 2003) and the resulting reduction in recruitment of small juveniles to the coastal waters of Baja. Juvenile loggerheads that forage off the Baja California peninsula depart from Japan as hatchlings and return as adults to their nesting beaches and thereafter stay in the Western Pacific (Bowen et al., 1995; Nichols et al., 2000).

The decline in average size in the olive ridley turtles may reflect the positive population trend that has been reported from the main nesting beaches over the past decade (Márquez et al., 1996). Very few small juveniles were found, and it appears that the Bahía Magdalena region is mainly used as a feeding ground for large juveniles and adults.

Our results strongly suggest that turtles are being taken at high and unsustainable rates in the study area and could partially explain why the populations have not recovered despite legal protection and long-term conservation work on the main nesting beaches. The protection of sea turtles on their developmental and foraging grounds is essential to provide a refuge for the critical juvenile life stages and to ensure that more turtles reach maturity and reproduce.

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