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The Hawksbill Turtle, *Eretmochelys imbricata*, in the Arabian Gulf

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ABSTRACT. – **Female hawksbill turtles (n = 291) were tagged nesting on four Arabian Gulf (= Persian Gulf) islands during the nesting seasons in 1991 and 1992. Hawksbills share their nesting beaches with green turtles, *Chelonia mydas*, and account for 17.8% of the total nesting. Adult females averaged 65.8 cm in straight carapace length and 50.8 cm in width. Average clutch size was 87.3 eggs, with 17.1 small yolkless eggs per clutch (70.2 normal eggs per clutch). Annual nesting frequency was 2.2 times per female with an average interval of 15.3 days between clutches. Incubation period averaged 61.2 days with emergence success rates of 46.4% in 1991 and 67.8% in 1992. Normal eggs weighed an average of 31.9 g and measured an average 37.0 mm maximum diameter. Hatchlings weighed 14.3 g and measured 38.0 in straight carapace length and 29.4 mm in width. The nesting season extended from May to July with a significant peak during June. Nesting was not particularly linked to tidal action, possibly because of the deep water and easy access to the beach. The majority of nesting took place between one and five hours after sunset. Little or no terrestrial predation threatens developing eggs or emerging hatchlings, although the islands are infested with mice and support large ghost crab populations. The squid *Sepioteuthis lessoniana* was observed to prey on hatchlings as they entered the sea. Saudi nationals do not generally eat turtle eggs, but an increasing number of foreign fishing crews collect eggs illegally. In general, adult hawksbill meat is regarded as poisonous by fishermen and is not eaten even when turtles are incidentally caught in nets.**

KEY WORDS. – **Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; reproduction; nesting; Arabian Gulf; Persian Gulf; Saudi Arabia**

Hawksbill turtles (*Eretmochelys imbricata*) are circumtropically distributed and often inhabit coral reefs where they feed on a number of invertebrates, sponges in particular. In the Middle East region, hawksbills have been studied in Oman (Ross, 1981), Sudan (Hirth and Abdel Latif, 1980), Yemen (Hirth and Hollingsworth, 1973; Green, 1996), Egyptian Red Sea (Frazier and Salas, 1984), and Saudi Arabia (Miller, 1989). In Saudi Arabia they are found in both the Red Sea and the Arabian Gulf (= Persian Gulf), but are only known to nest in significant aggregations on four of the Gulf's small islands. An aerial survey in 1991 and ground surveys to various locations between 1989 and 1992 have revealed no major clusters of nesting along the 1742 km Saudi Arabian Red Sea or the 450 km Arabian Gulf mainland coastlines (*pers. obs.*). Nesting and other reproductive data from Saudi Arabia therefore come entirely from the Gulf islands.

The turtle populations nesting on the islands in the Arabian Gulf have been the victims of increased man-induced pressures since the discovery of petroleum reserves in strata beneath the Gulf waters early in the 20th century. Since then, the region has experienced a significant growth in human population and industrial and commercial development, and several turtle feeding and foraging habitats are now being polluted and landfilled along the Saudi Gulf coastline. The offshore islands in the Saudi waters of the Gulf represent the only major hawksbill aggregation in the Kingdom, and are the focus of research and conservation efforts by the Saudi Arabian National Commission for Wildlife Conservation and Development (NCWCD).

Information herein is derived from two monitoring periods over the nesting seasons of 1991 and 1992. The survey that was carried out on the islands during the summer of 1991 was established in part as a response to the massive oil spill that resulted from the 1990–91 Gulf War. This momentum carried through to 1992, when the islands were again surveyed during peak nesting periods.

METHODS

Study Site. — The surveys were conducted on small four small uninhabited islands, Karan, Kurayn, Jana, and Jurayd, which lie 20 to 55 km off the Saudi mainland between 27°43'N, 49°49'E and 27°11'N, 49°59'E. The islands vary in circumference from 5.3 km (Karan) and 2.6 km (Jana) to less than 1 km (Kurayn), are all of low elevation (< 2 m) coral rock and sand with minimal halophytic vegetation (mainly *Suaeda* and *Salsola* sp.). The entire circumference of all four islands is suitable for nesting, including 100 m of exposed rock that extends to the upper tide limit on Karan and Jana which turtles can cross at any tide height. The islands support extensive nesting by green turtles (*Chelonia mydas*) averaging an estimated 450 to over 1100 females per year, primarily between April and September (Miller, 1989). Air temperatures during the nesting season fluctuate between 15 and 35°C, steadily increasing from June to September. The

islands are also used by thousands of pairs of nesting terns (*Sterna bengalensis, S. repressa, S. anaethetus*) during the nesting season. Thorough descriptions of the islands are given by Miller (1989) and Basson et al. (1977).

Methods. — In 1991 turtles were tagged from 25 May until 4 August on Karan and Jana, and from 27 May to 18 June on Jurayd. Although no turtles were tagged on Kurayn, the number of nesting attempts was estimated from body pit counts made on an irregular basis throughout the study periods. Monitoring in the 1992 season on Jana was from 3 to 24 June (to coincide with peak hawksbill nesting), and on Karan from 5 to 30 July (to coincide with peak green turtle nesting).

Small, four-wheel ATV motorcycles were used to patrol the perimeter of the islands to count the total number of nesting turtles. Team members were assigned sections of the shoreline and were assisted by a continuously moving ATV which carried equipment. Turtles were tagged, weighed, and measured as they returned to the sea after nesting, regardless of whether the nesting attempt was successful. Monitoring commenced shortly after nightfall (1800–1900 hrs), and continued into the following morning or until no more new turtles were nesting. Frequent but irregular circuits of the island were also made to monitor daytime nesting.

Adult females were measured following the descriptions by Limpus et al. (1983b). Measurements were taken with a fiberglass tape (± 0.1 mm) of the curved carapace length and width, straight carapace length and width, straight plastron length and width, head width, and tail length, which was measured from the tip of the tail to the tail/carapace junction. Turtles were tagged in the axillary position of both front flippers with titanium tags (Stockbrands Co. Pty. Ltd.) bearing the NCWCD address and contact numbers, one in Arabic and the other in Roman lettering. Adult turtles were weighed with a Salter spring balance (± 0.5 kg).

Renesting interval was defined as the number of days between different nesting attempts. Intervals of less than 3 days were excluded and considered false attempts, as were intervals greater than 18, which exceeds most reported internesting intervals (Bjorndal et al., 1985; Limpus et al., 1983a).

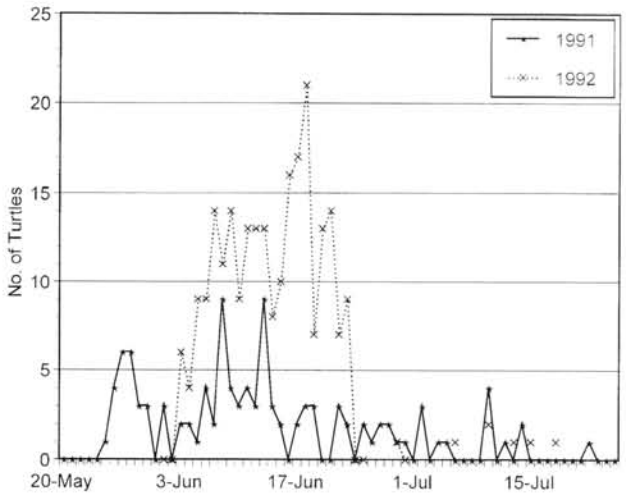

Figure 1. Hawksbill nesting season in the Arabian Gulf. Nesting commences around the end of May, peaks in mid-June, and the season is virtually over by early July.

Samples of ten normal eggs were removed from selected nests as the female proceeded with oviposition. The eggs were cleaned of adhered sand, weighed and measured, and returned to the nest before the conclusion of the egg-laying process. Meanwhile, the total number of eggs were counted as they were deposited.

Samples of ten hatchlings were obtained from various nests that were monitored through the incubation process. Two to three days after first emergence each nest was excavated and total hatchling emergence was determined by counting eggshells plus the number of undeveloped and partially developed eggs. Eggs that had no embryo developing after the incubation period were considered infertile and partially developed eggs were those that had started to develop, but which had not hatched.

Maximum egg diameter and hatchling straight carapace length (SCL) and width (SCW) were determined using dial scale calipers (±0.1 mm). Eggs and hatchlings were weighed with a Sartorius electronic balance (± 0.1 g).

RESULTS AND DISCUSSION

Tagging Study. — Both hawksbill and green turtles nest on the Saudi Gulf islands. Hawksbills accounted for 9.5% of total nesting in 1991, and 27.9% of nesting in 1992 (17.8% overall).

During the 1991 survey 43 hawksbills were tagged on Karan, 111 on Jana, and 10 on Jurayd. I estimate the total number of nesting attempts on Kurayn was 34 by an unknown number of individuals. This suggests that Jana is the most important hawksbill rookery. Three turtles were found carrying one of the two tags routinely applied by Miller in 1986 and 1987, and bore scars of the previous tags which were routinely replaced. Diffuse nesting was in effect when the team reached the island, and continued after the end of the project, with peak nesting during June.

In 1992, 120 new hawksbills were tagged on Jana, with only 7 tagged on Karan, strengthening Jana's claim as the main hawksbill nesting site. No turtles were tagged on Kurayn or Jurayd. Although no turtles from the 1986 or the 1991 tagging periods were encountered, four that were previously tagged in 1987 were resighted. During the 1992 survey, nesting had already commenced upon arrival on Jana, and the number of nesting hawksbill females peaked during June. In general, turtles showed sporadic nesting through the month of May, but continuous nesting did not commence until early June, and was finished by mid-July, with a peak toward the end of June (Fig. 1). This is a shorter nesting season than the April–June period summarized for the Arabian Gulf by Witzell (1983).

It was estimated that the majority (100% and 89%) of the turtles that would have nested each season were encountered during the surveys, based on simple mark-recapture probabilities. Turtles that had commenced nesting prior to the team's arrival may have been tagged on subsequent

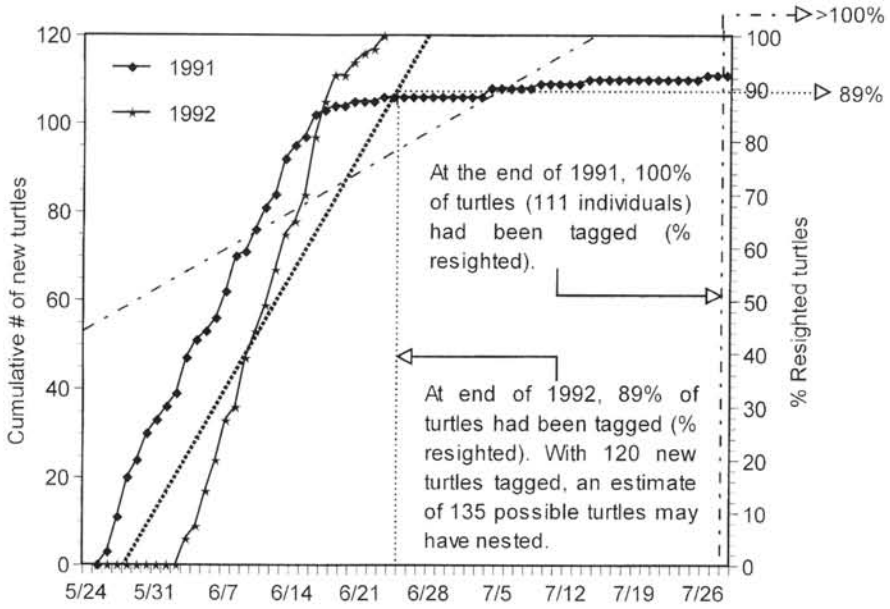

Figure 2. Estimate of size of nesting population based on recapture of tagged individuals. Linear trends in the % of remigrant turtles (dashed lines) suggest that on Jana 100% and 89% of turtles were tagged by the conclusion of the 1991 and 1992 seasons, respectively.

attempts during the survey, and nesting after the team's departure probably included turtles already tagged. Total number of females nesting on Jana in 1991 was estimated to be 111 and in 1992 was estimated to be 135 (Fig. 2). On Karan a total of 47 were estimated to nest in 1991. The shorter monitoring period in 1992 one month after peak nesting invalidates a total nesting population estimate. The density of turtles along Jana's 1600 m beach places the island among some of the world's most important hawksbill rookeries. For further studies on this species in the Gulf it is suggested that monitoring during June alone would yield the greatest results per unit effort.

Nesting Activity and Timing. — Nesting was as described by Carr et al. (1966b) and reviewed by Witzell (1983). Several mating couples were observed in the months preceding and during the nesting season in the waters between the islands and their fringing reefs, and outside the reefs. On Karan a lagoon northwest of the island was used by hundreds of mating pairs of green turtles but no hawksbills were ever seen coupled at this site. It is possible that both overcrowding and the hawksbill's earlier nesting season may account for their absence from what seemed to be a favored, sheltered mating lagoon. Females emerged on the beaches primarily at night but often in the late afternoon, with a minimum of 16 females nesting between 0900 and 1500 hrs. Complete emergence, nesting and return was accomplished in 1–2 hours ($\bar{x}$ = 1.67, n = 14). The only deviation from normal egg-laying occurred on 8 June 1991, when a turtle laid 40–45 eggs without shells, along with several eggs with shells. This may have represented a malfunction of the calcification portion of the oviduct.

Turtles emerged and nested after high tide rather than on the rising tide as reported by Ross (1981) and others. The reefs surrounding the islands do not pose a barrier to nesting turtles even at low tide, and their nesting is not linked to tidal fluctuations. Indeed, most nesting on the Gulf islands occurred during receding and incoming tides, not at the ex-

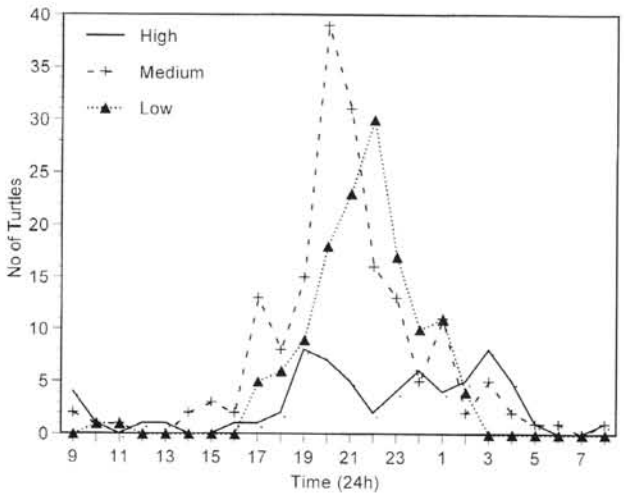

Figure 3. Nesting occurrence and tidal height. Most turtles emerged during incoming and receding tides. Although most nesting occurred at night, diffuse nesting occurred throughout the day.

Table 1. Summary of nesting female hawksbill turtle morphometrics collected in the Arabian Gulf during the 1991 and 1992 surveys. Measurements in cm (± 0.1), weights in kg (± 0.1). SD = standard deviation, n = sample size, CCL = curved carapace length; CCW = curved carapace width; SCL = straight carapace length; SCW = straight carapace width; PL = plastron length; PW = plastron width; TL = tail length; HW = head width; WGT = weight.

	CCL	CCW	SCL	SCW	PL	PW	TL	HW	WGT
Mean	71.2	64.2	65.8	50.8	52.4	47.8	13.4	10.4	39.1
SD	4.1	3.8	4.1	3.6	2.6	2.5	2.1	4.1	6.7
Min.	59.0	46.0	50.5	40.0	45.0	37.0	7.0	7.0	10.0
Max.	93.0	88.0	77.5	69.5	60.0	53.0	18.0	72.0	64.0
n	240	237	236	236	153	151	155	239	123

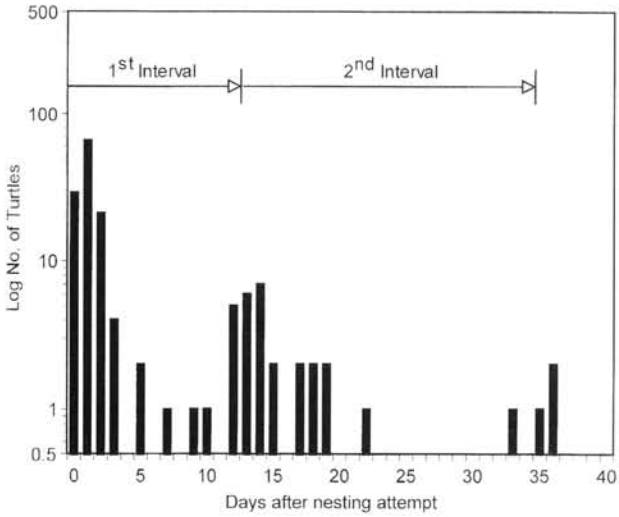

Figure 4. Renesting intervals for hawksbill turtles in the Arabian Gulf. A second nesting attempt occurs after 13 days (peak around 12–15 days), and a third occurs 22 days later (peak around 33–36 days).

treme highs and lows (Fig. 3). As in other parts of the region (Diamond, 1976; Hirth and Abdel Latif, 1980), the majority of nesting took place at night between one and five hours after sunset, with minor levels of nesting also found during daylight hours (Fig. 3).

Morphometrics. — Summarized morphometric data from adult females are listed in Table 1. Dimensions were not significantly different from those measured in previous studies in the Gulf ($z = 0.03$ to 0.66). However, both straight carapace length ($\bar{x} = 65.8$ cm, SD = 4.1, $n = 236$) and weight ($\bar{x} = 39.1$ kg, SD = 6.7, $n = 123$) were the lowest reported for any hawksbill population with the exception of the similar-sized Sudanese hawksbills (Hirth and Abdel Latif, 1980).

Comparisons of data sets over four years including data from Miller (1989) for 1986 and 1987 reveal little or no differences. It is probable that the four subsets encompass animals from various different nesting cohorts, and the overall means (curved carapace length = 71.2 cm, weight = 39.1 kg) are suggested as representative of the norm for Arabian Gulf hawksbills.

Annual Nesting Frequency and Interval. — Females laid an average of only 2.2 clutches in a season (SD = 0.12, $n = 42$). Over 75% of turtles emerged only once or twice, and the remainder (nine individuals) nested three times. During 1991, when diffuse nesting was in progress as the study began and nesting was over by the conclusion of the project, it is believed that most nesting attempts were recorded, providing a reasonably accurate record of nesting frequency. In 1992, due to the shorter period of time spent on the island, it was not possible to gather similar information.

The average renesting interval was 20.8 days in 1991 (SD = 11.8, $n = 13$) and 12.4 days in 1992 (SD = 1.67, $n = 30$), suggesting the possibility of variation for the same species at the same location between seasons. Overall, the first observed renesting interval for hawksbills (Fig. 4) in the Gulf was 13.0 days (± 0.85, $p = 0.05$, $n = 25$) which is shorter than the 16–19 days reported for other localities. A second renesting interval of 22 days (± 1.38, $n = 4$) is suggested by a series of later nesting returns (Fig. 4). On two occasions, turtles were found laying eggs on two successive nights, a phenomenon that has been recorded at a number of sites, but which is rarely reported (J. Miller and R.I.T. Prince, *pers. comm.*). Both of these occurrences may have been caused by disturbance, with the female returning the following night to finish laying the original clutch.

Table 2. Summary of egg weights and sizes for hawksbills in the Arabian Gulf. Clutch size includes small yolkless eggs; egg diameter and weight are based only on normal-sized eggs, which averaged 70.2 per clutch.

	Clutch Size	Number of small yolkless eggs/clutch	Egg Diameter (mm)	Egg Weight (g)
Mean	87.3	17.1	37.0	31.9
SD	19.28	9.20	2.32	4.36
Min.	36	4	22.0	16.0
Max.	127	42	49.8	62.0
n	63	63	724	724

Nest Site Fixity. — No turtles nesting on any of the islands were recorded nesting on another island during this 2-year study, suggesting some degree of site fixity at least in terms of island choice. Of the 281 hawksbills that nested on Jana and Karan, only 11 (0.06%) nested on the same 300 m section of the island.

Egg Deposition, Sizes, and Weight. — No significant differences were noted between the two years (all categories $z = 0.5$, $p > 0.01$), and summaries of egg deposition and morphometrics were calculated from the pooled data sets and are shown in Table 2. The smaller samples of eggs measured by Miller in 1986 and 1987 were not significantly different from those measured in the present study ($z = 0.5$, $p = 0.01$). The overall average number of eggs (87.3) was significantly higher than that found in 1986 and 1987 (74.8 and 64.5, respectively [Miller, 1989]) but still at the lower end of the range found at other rookeries: 81.2 in Yemen (Hirth and Abdel Latif, 1980) to 180 in the Seychelles (Diamond, 1976). The results fit a regional trend for other Middle East locations (see Hirth and Abdel Latif, 1980; Ross, 1981) where lower clutch size is common. It is not possible to link this to seasonal coldwater upwelling events but the turtle's feeding and reproductive habits may be affected by the extreme temperature fluctuations in the Gulf (15–35°C), resulting in similar reproductive output.

Incubation Period. — Incubation periods on Jana in 1991 were 62 to 64 days ($\bar{x} = 63.0$, $n = 4$). No hatchlings were found on the island prior to the emergence of the above nests, so it is doubtful that incubation periods could have been less than this, but they might have been longer. During the 1992 survey, incubation periods were 58–62 days ($\bar{x} = 60.3$, $n = 4$). Overall, incubation periods averaged 61.6 days (± 1.92, $p = 0.05$). Miller (1989) reported incubation similar periods of just less than 60 days for 1986 and 1987.

Hatching Success (Egg Mortality). — A summary of hatching success is presented in Table 3. No hatchlings were

found in any of the nests or sand columns so hatching success was considered the same as emergence success. The mean success rate in 1991 was 46.4% (range, 2.4–79.8, $n = 23$), while in 1992 it was 70.9% (range, 54.3–81.9, $n = 7$). The 1992 success rate was significantly higher than that found in 1991 ($z = 0.895, p < 0.05$), but still lower than the 87 to 89.9% reported for 1986 and 1987. The present rates are at the lower end of the global range and warrant further investigation for causal factors, such as the possibility of effects of hydrocarbon contamination.

Hatchling Sizes and Weights. — A summary of the morphometric findings on hatchlings is presented in Table 3. There was no significant difference between 1986 and 1987 hatchlings (SCL: $z = 0.5$, WGT: $z = 1.0$, $p = 0.01$). Lengths and weights also fell toward the lower end of the range across other worldwide sites (Witzell, 1983).

Mortality. — There was no active terrestrial predation on live hatchlings. On rare occasions, dead hatchlings were found being eaten by ghost crabs (*Ocypode* sp.) and hermit crabs (*Coenobita* sp.) and on Karan by the common mouse (*Mus musculus*). The crabs and the mice, as abundant as they were, were never seen preying on live hatchlings. Sea birds were not seen to actively prey on hatchlings, even though close to 100 gulls (*Larus* sp.), hundreds of thousands of terns (*Sterna bengalensis*, *S. repressa*, *S. anaethetus*), and a handful of herons (*Ardea* sp.) were resident on the islands at the time. Though most terns were actively feeding after dusk, when hatchlings emerged, they preyed on smaller fish and were not seen to return to the beach with hatchlings.

On one occasion, while releasing hatchlings close to the water's edge, a squid (*Sepioteuthis lessoniana*) was observed to embrace a hatchling within its tentacles and try to swim away with it. Upon closer inspection, the shoreline was found to have a large number of 'waiting' squids, a pattern which was repeated on several occasions.

A major cause of hatchling mortality on both Jana and Karan was discarded fishing nets on the beach. Many of these nets were removed by the team, but several groups of over 100 hatchlings had already entangled themselves and died by the following day.

Adult turtles are prone to attacks from large fish, probably sharks, as evidenced by nine turtles that were missing portions of the rear end of the carapace and partial or entire rear flippers. The Arabian Gulf is home to numerous species of sharks, but no records have been published on the incidence of turtles in shark stomachs for the Gulf region.

Table 3. Summary of hawksbill hatching success and hatchling morphometrics.

	Clutches		Hatchlings		
	No. Eggs	% Hatched	SCL	SCW	WGT
Mean	85.2	52.1	38.0	29.4	14.3
SD	18.03	21.76	1.89	1.49	1.96
Min.	43	2.4	28.8	25.7	10.0
Max.	125	81.9	41.9	39.2	20.1
n	31	31	261	261	261

Saudi nationals do not generally eat turtles or their eggs. However, in the Arabian Gulf many fishing boats are now manned by foreign nationals who do, and unless the islands are patrolled, these fishermen frequently dig up clutches of eggs. The fishermen are also known to take adults on an opportunistic basis (Miller, 1989). During the present study, the only evidence of adult turtles being taken was one butchered adult green turtle found on Jana in July 1992. One hawksbill was found dead (apparently of natural causes) on Jana on 12 July 1992.

In the Gulf and the southern Red Sea, hawksbills are considered poisonous by the villagers and not taken and nesting is diffuse enough that eggs are rarely taken along the mainland coast of either the Gulf or the Red Sea.

No adult turtles were seen to be outwardly suffering due to petroleum-related pollution, even though after the Gulf War many were expected to be completely covered in oil. Only four oiled hawksbills were treated at the Jubail Wildlife Rescue Center during the oil-spill crisis (*pers. obs.*), and only 13 turtles were found to be moderately-to-heavily oiled during the 1991 survey. The tar on the rocky portions of the shorelines from previous oil spills was found to be more of a threat to emerging hatchlings as they attempted to reach the sea. During the hot daylight hours, the tar was melted into a tacky 'glue' impossible to crawl over. However, because the majority of hatchlings emerged after sunset the tar had cooled and resolidified sufficiently to allow passage. Although hatching success was lower than that reported prior to the Gulf War oil spill, it is not possible to link this directly with oil contamination on the beaches. Oil was only found to cover the superficial 10–20 cm of sand on short portions of only Jana and Karan and clutches were laid in upper beach areas above the region into which oil had penetrated, in addition to non-oiled areas. Moreover, the most heavily oiled beaches on Karan were replaced with clean sand in a cleanup project that ended shortly before the beginning of the nesting season. It is doubtful that the short period between the spill and the nesting season allowed the contamination of the upper beach areas where nesting occurred.

Shortly after the conclusion of the 1990–91 Gulf War, and prior to the commencement of nesting, the beaches on all four major nesting beaches were cleared of accumulated debris, flotsam and jetsam, in a rapid four-day, intensive cleanup project. In general, it may be accepted that the oil spilled during the Gulf War had little or no detrimental effect on the 1991 nesting populations. However, long-term monitoring of both green and hawksbill populations may reveal delayed effects, possibly linked to the turtle's feeding habits and requirements.

Migration. — One individual released at Batina Island close to the mainland was found nesting on Karan (ca. 78 km away) 79 days after release. It is unknown when she arrived near the island prior to nesting. This turtle had been found near-dead on the mainland beach after the oil spill, and was treated at the Jubail Wildlife Rescue Center. It went on to lay two clutches of eggs which developed normally.

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