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The Green Turtle, *Chelonia mydas*, in the Saudi Arabian Gulf

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Saudi Arabian waters host two species of nesting marine turtles, the green turtle, *Chelonia mydas*, and the hawksbill, *Eretmochelys imbricata*. Other species have been reported for the Gulf waters but do not nest in Saudi Arabian territories (Miller, 1989; Ross and Barwani, 1982). In the Arabian Gulf, the primary nesting sites for these turtles are the islands of Karan, Jana, Juraid, and Kurain. The small islands (size range: 7.5 ha to 1250 ha) lie off the Saudi Arabian east coast between 27°43'N, 49°49'E and 27°11'N, 49°59'E (Fig. 1), and collectively host several thousand turtles each year. Thorough descriptions of the islands can be found in Basson et al. (1977), Miller (1989), and Pilcher (1999).

The 1991 and 1992 nesting seasons on Karan, Jana, and Juraid were monitored as part of an assessment of the status of marine turtles by the National Commission for Wildlife Conservation and Development (NCWCD), in part to determine the immediate effects of the 1991 oil spill that resulted from the Iraq-Kuwait war, and as part of the Saudi Arabian ongoing commitment to wildlife conservation.

Methods. — In 1991 green turtles turtles were tagged from 25 May until 4 August on Karan and Jana, and from 27 May to 18 June on Juraid. No turtles were tagged on Kurain, but nesting attempts were estimated from pit counts made on an irregular basis throughout the study periods. Monitoring in 1992 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). Field methodology was as described by Pilcher (1999).

In addition, capture of male turtles was effected by carrying out "rodeo" style captures using small boats in the shallow waters surrounding Karan and Jana islands. The boats were used to patrol the lagoon area until a male turtle was spotted, which was then chased until a crew member could dive in and pull the turtle into the boat to be measured, tagged, and immediately released.

Results

Tagging Study. — A total of 895 green turtles was tagged on the three islands in 1991 and 530 on two islands in 1992 (Table 1). Karan appeared to be the most important green turtle rookery of the three. Eleven turtles carried tags applied by Miller in 1986 and 1987, and new tags were applied to replace previous ones that had been lost. In 1991, diffuse nesting was in effect when the team reached the islands, and continued after the end of the project. Peak nesting occurred during July. In 1992, surveys were only carried out on Jana and Karan. Fifteen turtles from 1986 and 1987 and one from 1991 were encountered. Diffuse nesting had commenced upon arrival on Jana in June and had become relatively dense on Karan in early July. Turtles nested sporadically until the end of May, continuous nesting did not commence until early June, and was finished by early August with a peak during July.

Based on mark-recapture probabilities, a large portion of the turtles that nested each season were encountered during the surveys. After turtles were tagged and allowed to return to the internesting habitat, they were assumed to mix evenly among non-tagged individuals. During subsequent nesting attempts, the ratio of tagged turtles to non-tagged turtles was used to estimate the percentage of that season's turtles that had been tagged up to that point. The trend indicated by changes in the percentage of tagged turtles over time was used to estimate the size of the annual nesting populations (Fig. 2).

By the end of the 1991 monitoring period, the linear trend in recaptures reached a maximum of 63% (dotted line and arrow, Fig. 2). Extrapolation from the total number of turtles that were tagged that season (559) suggested a possible total nesting population size of 887. By the end of the 1992 monitoring period, an estimated 89% of emerging turtles were already tagged (dashed line and arrow, Fig. 2). Extrapolation from the number of turtles tagged that season (408) suggested a possible total nesting population size of

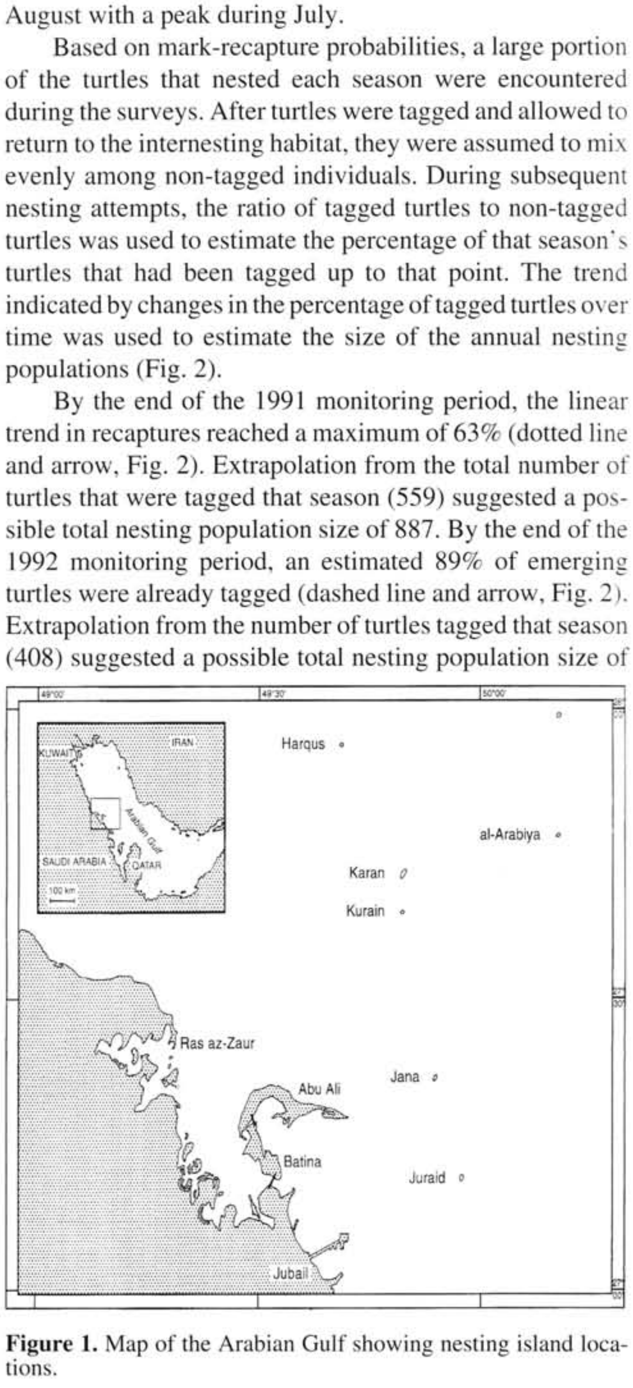

Figure 1. Map of the Arabian Gulf showing nesting island locations.

Table 1. Number of female green turtles recorded as nesting on the Arabian Gulf islands, 1991–92 (no survey on Juraid in 1992).

Year	Karan	Jana	Juraid	Total
1991	559	302	341	895
1992	408	122	—	530

458. In a similar manner, a total of 308 greens were estimated to nest on Jana in 1991. No estimate was made for Jana in 1992, as surveys were made one month before peak green turtle nesting.

Nesting Activity and Timing. — Numerous 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 throughout the months of June and July.

Nesting was not linked strongly to tidal fluctuations (Fig. 3). Turtles emerged predominantly during mid- (rising and falling) and low tides. The reefs surrounding the islands did not prevent nesting even at low tide. The majority of nesting took place at night, between one and five hours after sunset, with minor levels of nesting found during the day. Complete emergence, nesting, and return was accomplished in 1–2 hours (mean = 1.59, $n = 74$). Six females were found emerging with males still mounted. Invariably these males released their hold by the time the female had emerged 5–10 m, and rapidly returned to the sea.

Morphometrics. — Summarized morphometric data from males and females are listed in Table 2. Turtles were not significantly different from those of previous years in the Gulf. Both straight carapace length (mean = 91.5 cm, SD = 4.60, $n = 1216$) and weight (mean = 108.5 kg, SD = 14.63, $n = 619$) were at the lower end on a global scale. Males were significantly smaller than females ($z_{SCL,0.05} = -3.894$, $p < 0.001$).

Renesting Occurrence and Interval. — The first renesting interval (greater than 5 and shorter than 30 days) was 14.1 days (SD = 4.58, $n = 643$) which is consistent with that reported for other localities. However, the second renesting interval was of 13.0 days (SD = 3.89, $n = 223$), the third of 11.3 days (SD = 2.56, $n = 56$), and the fourth was by a single individual that returned after 10.0 days, indicating a gradual shortening of the internesting period with progressive nesting attempts (Fig. 4). Although sea temperature data was not collected, ambient air temperatures generally declined gradually throughout the surveys. It was believed therefore that sea temperatures did not rise during these times, and that the shortening of the renesting interval was regulated by a physiological rather than a thermal process.

Choice of Nest Site. — Beach use was significantly ($\chi^2_{Karan} = 3.04\ E^{-265}$, $\chi^2_{Jana} = 3.24\ E^{-74}$, $p = 0$) non-uniformly distributed on both islands (Fig. 5). Only one (0.0007%) of the renesting greens tagged on Jana was ever found on Karan during either survey period (ca. 40 km apart), suggesting a significant degree of site fixity at least of 'island' magnitude.

Egg Deposition, Sizes, and Weight. — Clutch and egg data were pooled as no significant differences were noted between years (Table 3). The average number of eggs was not significantly different from the smaller samples of eggs measured in 1986 and 1987 (average = 87.1; Miller, 1989), and at the lower end of the range found at other rookeries (Hirth, 1997). Clutch size was not significantly correlated with body size ($r^2 = 0.056$, $p > 0.05$) in contrast to the case at other rookeries.

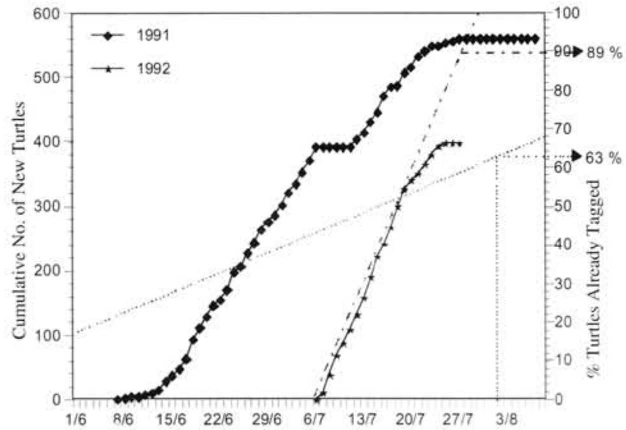

Figure 2. Estimates of the size of the green turtle nesting population based on recapture of tagged individuals. Symbols represent total number of resighted (already tagged) turtles. Diagonal lines represent linear regression (trends) in the percentage of resighted turtles nesting each night (see text for details).

Incubation Period and Hatching Success. — Incubation periods on Jana in 1991 were 62 to 64 days (mean = 62.8, $n = 4$). During the 1992 survey, incubation periods were 59 to 65 days (mean = 61.8, $n = 5$). Sample sizes were small due to the length of the monitoring period, but were similar to the 62.5 days reported for 1986 and 1987 (Miller, 1989).

The mean hatchling emergence success rate was 84.7% (range: 53.7–96.8%, $n = 21$ clutches) and was significantly higher than that found in other worldwide rookeries (Hirth, 1980, 1997). Emergence success was not correlated with clutch size ($r^2 = 0.0032$, $p > 0.05$).

Hatchling Sizes and Weights. — A summary of the morphometric findings for hatchlings is presented in Table 4. There was no significant difference between the 1986 and

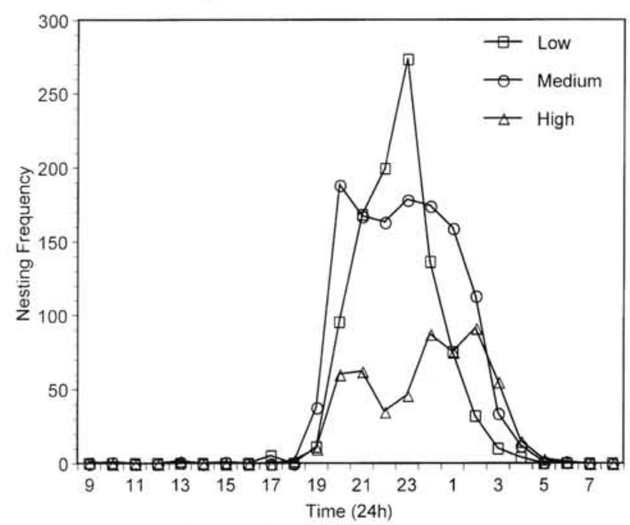

Figure 3. Frequency distribution of nesting over 24 hours by tide height. Symbols indicate tide height.

Table 2. Summary of morphometric data for adult green turtles in the Arabian Gulf. Measurements in cm and kg; x = mean; 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; WT = weight.

		CCL	CCW	SCL	SCW	PL	PW	TL	HW	WT
Females	x	97.7	87.9	91.5	69.6	76.7	66.7	21.0	12.4	108.5
	SD	4.73	4.88	4.60	4.59	4.06	3.81	3.19	1.14	14.63
	Min	41.0	33.5	70.0	55.5	59.0	53.0	11.0	9.0	54.0
	Max	114.0	104.0	104.0	97.0	96.0	84.0	49.0	21.0	168.0
	n	1391	1384	1216	1229	693	693	697	1362	619
Males	x	92.5	84.2	88.2	67.4	72.4	62.1	47.8	12.1	87.8
	SD	3.26	3.28	5.08	4.63	3.31	3.88	5.55	0.75	12.40
	Min	84.0	78.0	70.5	60.0	65.0	55.0	35.0	11.0	64.0
	Max	97.0	92.0	95.0	84.0	80.0	74.0	57.5	14.0	120.0
	n	31	30	25	26	29	29	31	31	22

1987 hatchlings when compared with those from this study. Lengths and weights (means = 47.7 mm and 22.3 g) generally fell within the range across other worldwide sites. The sand temperature recorded as the hatchlings emerged from the sand averaged 33.9°C.

Mortality. — There was no systematic terrestrial predation on hatchlings once they emerged and crawled to the sea. Dead hatchlings were occasionally eaten by ghost crabs (*Ocypode* spp.) and hermit crabs (*Coenobeta* spp.) and on Karan by the common mouse (*Mus musculus*). The crabs and the mice, which are very abundant, were not ever seen chasing and capturing live hatchlings. Sea birds were not observed preying on hatchlings, even though gulls, herons, and thousands of terns were resident on the islands. Recent findings suggest this may not always be the case, as in 1994 terns were regularly seen feeding on hatchlings when small fish were not available (P. Symens, *pers. comm.*).

On one occasion, a squid (*Sepioteuthis lessoniana*) was observed to entangle a hatchling within its tentacles. A large number of these squids were noted 'waiting' along the shoreline on several occasions.

The Arabian Gulf is inhabited by numerous species of sharks, but no records have been published on the incidence of turtles in shark stomachs for the Gulf region. Flipper damage and/or loss was more common than damage to the carapace, although 11 turtles had healed scars from earlier encounters. One turtle had a 10 cm hole through the carapace posterior to the left front flipper, and a second had a V-shaped cut through the nuchal scutes, neither of which were believed to be shark-inflicted. A number of turtles exhibited signs of predator damage in the form of missing portions of the rear end of the carapace and partial or entire rear flippers (Table 5).

A number of females became disoriented and headed inland after nesting rather than returning to the sea. Both Jana and Karan are littered with carcasses, and six turtles were found during this study that had wandered in the wrong direction. Five of these were turned and assisted back to the sea. One succumbed to the heat.

Saudi nationals do not generally eat turtles or their eggs. However, in the Arabian Gulf many local fishing boat crews are being replaced by individuals of other nationalities who do, and unless the islands are patrolled, the 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 adults being taken was one adult green turtle that was found butchered on Jana in July 1992.

Effects of the Oil Spill. — No adult turtles were obviously stressed due to petroleum-related pollution. Eleven turtles were moderately-to-heavily oiled during the 1991 survey, and were washed with mild detergent prior to their return to the sea. The most heavily oiled sand on Karan was replaced with clean sand shortly before the nesting season, virtually eliminating the threat of direct contact with the oil. The long-term accumulation of tar on the rocky portions of the shorelines was a potential threat to emerging hatchlings.

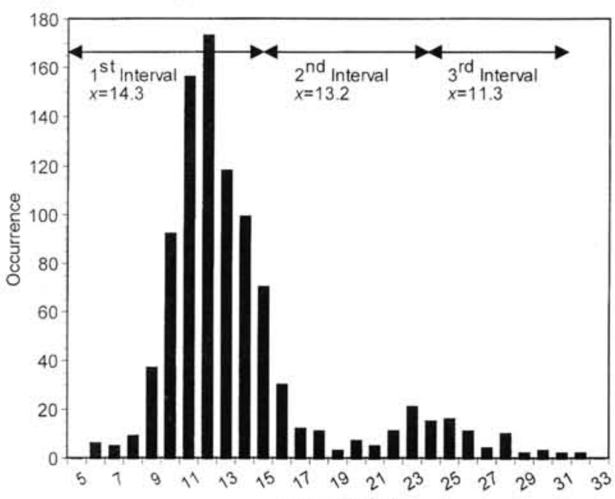

Figure 4. Renesting intervals for green turtles in the Arabian Gulf, 1991–92. Intervals represented by arrows represent means.

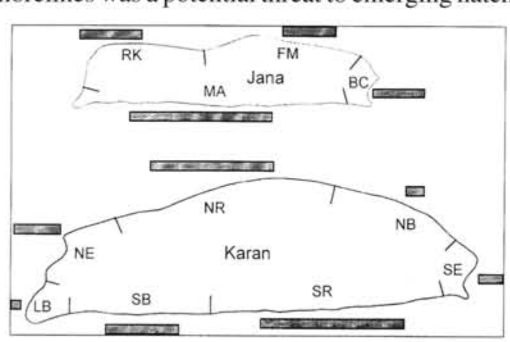

Figure 5. Beach use at the two primary nesting islands. Horizontal bars are scaled to represent nesting volume at each of the beach sectors. Islands not drawn to scale or north-aligned.

Table 3. Morphometric summary of green turtle eggs in the Arabian Gulf; x = mean.

	Clutch Size	Number Deformed	Diameter (mm)	Weight (g)
x	86.9	5.0	42.7	46.3
SD	22.63	5.24	2.61	7.41
Min	33	0	35.0	30.0
Max	146	22	50.4	60.0
n	42	42	422	423

Table 4. Morphometric summary of green turtle hatchlings, Arabian Gulf. Measurements in mm and g; x = mean; Total = total number hatchlings emerging per nest; % Hatched = % of eggs that hatched per nest; SCL = straight carapace length; SCW = straight carapace width, WT = weight.

	Total	% Hatched	SCL	SCW	WT
x	94.8	84.7	47.7	37.9	22.3
SD	18.26	11.65	1.78	1.83	2.15
Min	55	53.7	41.4	32.0	15.0
Max	131	96.8	51.4	42.0	29.0
n	21	21	162	162	162

because the tar melted into a tacky 'glue' during the hot midday hours. However, because the majority of hatchlings emerged after sunset the tar had cooled and resolidified sufficiently to allow passage.

Discussion

Annual fluctuation in nesting numbers has been documented at a number of rookeries (Bjorndal, 1980; Limpus et al., 1984) and was the case on the Gulf islands. Including data collected by Miller in 1989, nesting populations of green turtles on Karan have so far fluctuated between 450 and 1155 females, and on Jana between 464 and 654 females.

There was a low incidence of site fixity between successive nesting attempts on an individual basis. However, there was a strong site fixity at the island level, where only one individual (0.0007%) attempted to nest on both islands, a distance of 40 km. Even over successive nesting seasons there were no inter-island movements. Limpus et al. (1992) found that inter-island migration among Australian rookeries was low, even when the islands were close together. Similarly, inter-island movement was low in Sarawak (Hendrickson, 1958) and in Sabah (Pilcher and Basintal, in press). In the Arabian Gulf at least, it is probable that once the nesting island has been determined from the first nesting season after maturity, the actual nesting location on the island is not important.

An important feature of the remigrant turtles, apart from their lack of within-island nest site fixity, is their scarcity.

Table 5. Damaged and missing flippers on female green turtles. Values represent number of individuals.

	Damaged		Missing	
	Front	Rear	Front	Rear
Right	13	2	3	7
Left	7	4	3	1

Only 11 previously tagged individuals were encountered in 1991, while 15 were encountered in 1992. Given the tagging procedures used by Miller in 1986 and 1987, the probability of tag survival was extremely high (as per Limpus, 1992) and was evident in that most remigrants had at least one tag still intact. Bjorndal (1980) noted from tag returns that remigration after the first year did not exceed 40% in Tortuguero, and that by the fifth year (minimum resighting interval from 1986–91 during the present study) could be as low as 8%. The remigrant turtles encountered during this survey represent less than 2% of the originally tagged individuals, even though the Arabian Gulf population is not subject to the fishery pressure, either intentional or accidental, that Tortuguero turtles face. It is possible that the 1991 oil spill was responsible for a high level of mortality among all adult turtles, reflected in this study by the low recapture rates. Detection of an increase in recapture rates in future seasons would substantiate this belief or reveal whether this is a long-term trend; i.e., consistently low return rates, as occurs in Sabah, Malaysia (Pilcher and Basintal, in press).

One individual tagged in 1991 returned the following year, even though green turtles do not generally remigrate on annual cycles, and internesting periods of 2–5 years are normal (Carr and Hirth, 1962; Balazs, 1980; Bjorndal, 1980). In 1991, this individual attempted to nest three times, one of these times successfully. In 1992, she was found attempting to nest only once, unsuccessfully. However, as pointed out by Mortimer and Portier (1989), the simple act of emerging on the beach usually indicates intention to nest, and it is possible that this individual may have nested unseen earlier or later the same season. The one individual represents a very small percentage of the population and although not common, this record does indicate that green turtles have the ability to nest with only a one-year period separating remigrations.

Clutch size in the Arabian Gulf (86.9 eggs) was among the smallest reported for the Middle East (Oman: 97–103.5, Ross and Barwani, 1982; South Yemen: 106, Hirth and Carr, 1970; Red Sea: 99.7, Pilcher, in press), and indeed on a global scale (see Balazs, 1980; Hirth, 1997). Adult females were also at the lower end of the size scale. It is possible that the environmental extremes that prevail in the Gulf (e.g., temperature range: 19–33°C; Hunter, 1986) interfere in some manner with the digestive and assimilative process, which results in lower food availability and in turn lower reproductive potential. Although seagrasses are relatively abundant in the Saudi portion of the Arabian Gulf (Basson et al., 1977), these areas have not been found to support significant foraging turtle populations (relative to the size of the nesting populations). It is possible that the nesting turtles migrate as far as the United Arab Emirates (UAE), some 1400 km away, to forage on the pastures in the southern Gulf. The UAE is known to support a significant number of turtles, but not many are known to nest on their beaches (G. Balazs, *pers. comm.*). Energy expended by the Saudi nesting populations to undertake migrations is thus unknown. However, because nearly all turtle populations in the world undertake nesting migrations (Hirth, 1997), this is not believed to be a causative factor in reduced clutch size on the global scale.

The attempt by many turtles to nest despite missing flippers is noteworthy. Those turtles missing front flippers were noted to have difficulty in excavating the body pit, which invariably was not as deep as that dug by normal turtles. The females missing rear flippers had difficulty in excavating egg chambers, and were often assisted by team members. It is believed that under natural conditions these turtles would not contribute significantly to the population's reproductive output. Additionally, these surviving turtles with amputated limbs are probably a small fraction of the actual number of victims, and predation by large carnivores such as sharks and groupers on adult turtles is likely underestimated (Balazs, 1980). The tiger shark (*Galeocerdo cuvieri*), known as a predator on adult turtles (Balazs, 1980; Witzell, 1987), is a common shark off the nesting islands although we have no reports on actual predation at these sites.

Overall, it was believed that the oil from the 1991 Gulf War oil spill had little or no detrimental effect on the 1991 nesting populations and their eggs and hatchlings. The lack of widespread adult turtle mortality (less than 10 female green turtles were stranded on the mainland coast after the 1991 oil spill [NCWCD, unpubl. data]) and the normal nesting process observed on the beaches suggests that the oil spill had no acute effect on nesting adults. Nor was the oil spill believed to have affected actual egg development because clutches were laid above the region into which oil had penetrated. Although the oil spill did not have any obvious short-term effects on the sea turtles, the oil could contaminate their foraging pastures and the sand in which they lay eggs. The small size of the eggs may be a symptom of oil contamination, and sampling in future years would reveal if this was normal for the population. However, eggs from 1991 and 1992 were not significantly different in size and weight, but could have been similarly affected. Long-term studies might also reveal whether there are any chronic effects from ingestion of contaminated sea grasses. Continued monitoring is needed to determine the long-term effects of oil pollution on sea turtles in the Arabian Gulf.

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