

Tracking Hawksbills in Kuwait: Contributions to Regional Behavioral Insights

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ABSTRACT. – Hawksbill turtles from nesting areas in the south of the Arabian/Persian Gulf have been shown to migrate to numerous individual foraging sites across the region and undertake “summer migration loops” (SMLs) to avoid the most extreme sea temperatures. We tracked hawksbills nesting in Kuwait ($n = 4$) that migrated to hitherto undescribed foraging sites but showed no evidence of SMLs despite experiencing water temperatures greater than 33°C. Increasing the sample size for Kuwait turtles, tracking males, and publishing results from other important hawksbill nesting areas in Saudi Arabia are recommended to get a fuller indication of potential behavioral plasticity in the region.

The ability to track sea turtles over large spatial and temporal scales enables researchers to obtain unbiased behavioral insights (Godley et al. 2008), assessment of turtles’ environmental niches (Pikesley et al. 2015), and effectiveness of marine protected areas for conservation and management (Scott et al. 2012). The Argos satellite tracking system (www.argosinc.com) has been widely adopted as the preferred method for tracking sea turtles given its global coverage and potential for tracking durations in excess of a year (Godley et al. 2008).

Costs for data obtained from satellite tracking are not insubstantial; hence, maximizing their usefulness for conservation should be considered a priority. Publishing results and sharing data sets are ideal ways to achieve this. Combining individual studies, often with limited sample sizes, permits better regional assessments for ecological studies and conservation management. A collaborative turtle project (Emirates Wildlife Society–World Wide Fund for Nature [EWS-WWF] 2015) that incorporated transmitters deployed specifically for the project and data from other tags from the area covered Iran, Qatar, the United Arab Emirates, and Oman and provided important behavioral insights for hawksbill sea turtles (*Eretmochelys*

imbricata) in the southern Arabian/Persian Gulf (hereafter referred to as the Gulf). Analysis and interpretation of the results from this project have subsequently been made accessible through peer-reviewed publications (Pilcher et al. 2014a, 2014b) and a scientific report (EWS-WWF 2015). Consequently, further studies can now be assessed in the context of those findings and highlight knowledge gaps and priorities for further research.

To identify migration routes and foraging areas, we undertook tracking at 2 of the 3 hawksbill turtle nesting sites in Kuwait. This article compares results from our study with those obtained elsewhere in the Gulf to add further insight into hawksbill behavior across the region.

Methods: Field Methods. — Study turtles were encountered on the beach at night during a nesting emergence in 2010. If the turtle laid a clutch of eggs, it was allowed to complete the nesting process and move away from the nest site before we retained it on the beach in a large wooden frame for transmitter attachment. If the turtle did not successfully nest, it was enclosed in the frame when we were certain it was returning to the sea. Two turtles were selected at Umm Al Maradim Island (lat 28.6816°N, long 48.6525°E) and 2 from Qaru Island (lat 28.8152°N, long 48.7769°E) (Fig. 1). Curved carapace length notch-to-tip (CCLn-t; Bolten 1999) was measured for each individual prior to transmitter deployment and for other turtles encountered on the beach that were not tracked. Argos-linked, Kiwisat 101 PTT (Sirtrack Ltd; www.sirtrack.com) transmitters were fixed to the second vertebral scute of the turtles using 2-part Sika Anchorfix 3+ epoxy after the methods of Godley et al. (2002). Transmitters were duty cycled to be continuously on. To extend battery life, a saltwater switch inhibited transmissions when the transmitter was submerged.

Data Methods. — Argos (www.argos-system.com) data were automatically downloaded and compiled by the Satellite Tracking and Analysis Tool (Coyne and Godley 2005). To enable direct comparison with a major hawksbill tracking study from the region (EWS-WWF 2015), we undertook track processing and filtering following Pilcher et al. (2014a, 2014b). That is, we selected location fix qualities 3, 2, 1, 0, A, and B and filtered these data to exclude implausible fixes, such as positions many kilometers from the previous fix, resulting in highly acute angular movements (e.g., locations over land or those requiring travel speeds of $\geq 5 \text{ km h}^{-1}$). To reduce autocorrelation, we selected 1 fix per turtle per day, choosing the highest-quality fix for that day. When there was more than one fix of equal “best” quality, the 1 nearest to midday was selected.

We then subdivided the routes into internesting and postnesting periods where internesting was categorized as the period postdeployment until departure from the nesting site. No turtles were reobserved on the nesting beaches, and Argos locations were of too low accuracy to identify nesting activity with any degree of certainty; therefore, we

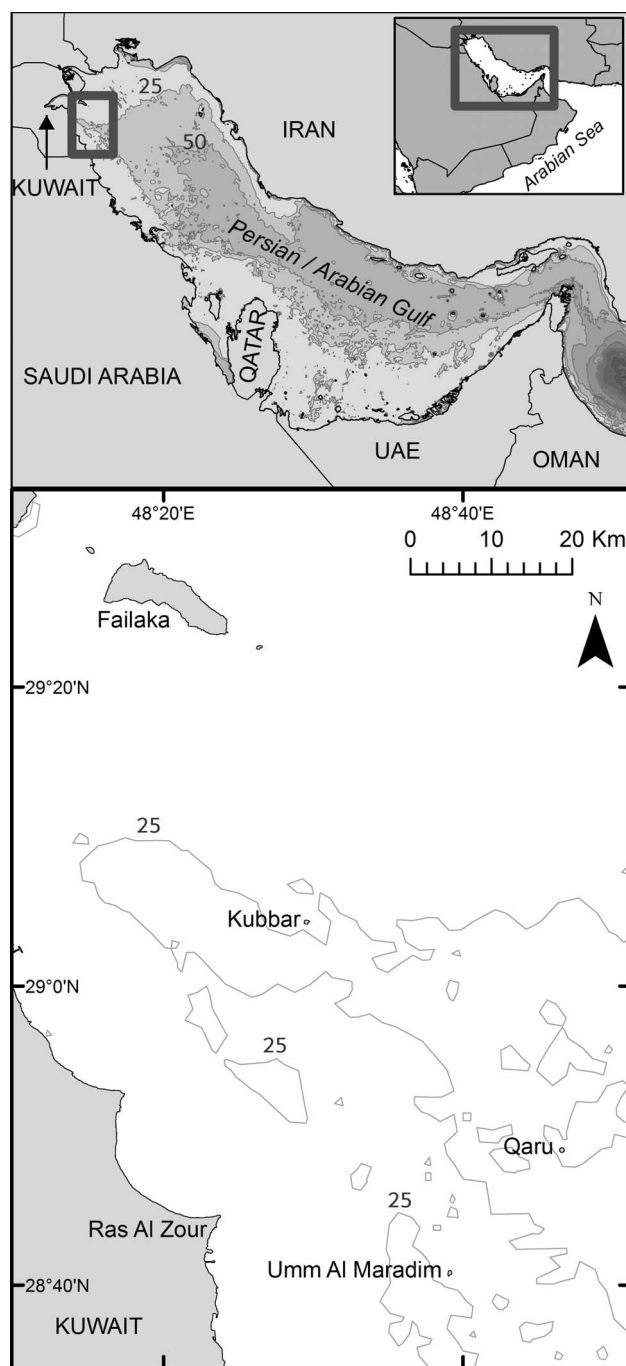


Figure 1. Location of Qaru and Umm Al Maradim Islands, where transmitters were deployed, shown in a regional context.

derived an estimated minimum clutch frequency for each turtle by adding an additional nest to the turtle's observed nesting event for each 2-wk internesting interval (Pilcher 1999) that the turtle remained near the its nesting site.

We identified migratory periods and foraging areas through interpretation of swim speeds and changes of track direction. Migrations were characterized by faster, directed travel, and conversely, foraging activity was typified by slower swim speeds and seemingly random heading changes (Pilcher et al. 2014b).

To assess possible thermal influence on turtle movement and behavior, spatially and temporally congruent sea surface temperature (SST; AHVRR data from the National Oceanic and Atmospheric Administration) was automatically assigned to each location of the filtered track by STAT. Ocean depths presented herein were derived from the GEBCO 2014 bathymetric chart (Weatherall et al. 2015).

Results: Turtle Size, Tracking Duration, and Clutch Frequency. — One turtle encountered on the beach on Qaru with a CCLn-t of 71.5 cm was measured in addition to the 4 tracked individuals. Adult female hawksbill turtles in Kuwait had a mean CCLn-t of 73.3 cm (SD, 4.2; range, 69.0–78.5 cm; $n = 5$). Tracking durations were highly variable, ranging from 73 to 826 d (Table 1). Internesting tracking periods ranged from 2 to 19 d, producing estimated minimum clutch frequencies of 1 to 2 nests for the 4 tracked turtles, with a mode of 2 (Table 1). The 3 turtles presumed to nest more than once remained within a few kilometers of their nesting area during the internesting period but then migrated to other distinct foraging locations.

Migrations. — There was no overlap between the foraging areas of the 4 tracked turtles. After completion of its breeding season, turtle A moved westward, closer to mainland Kuwait. Its tracking duration was 826 d, and in that time, it moved extensively from the coast, offshore past Qaru Island with 2 short loops south into Saudi Arabian waters (Fig. 2A). Turtle B migrated south into Saudi Arabian waters, where it utilized 2 separate and widespread foraging areas, switching between the 2 via circuitous routes for a total of 134 d (Fig. 2B). Turtle C migrated west-northwest from its nesting site and established a residency in coastal waters off mainland Kuwait (> 19 d). Transmissions ceased for almost 8 mo, and when they restarted, the turtle had migrated south to an offshore foraging site in Saudi Arabia, where it resided until transmissions ended (83 d; Fig. 2C). Turtle D migrated west to nearshore waters of mainland Kuwait, where it remained for 58 d. It then moved eastward again into open seas for 10 d until transmissions ceased (Fig. 2D). The last 3 d of transmitter activity (30 August–1 September 2010) indicated abnormal behavior of the turtle, namely, a high frequency of the more accurate Argos LCs 1–3 and smooth circling movements, suggesting that the turtle was at the surface and possibly dead, floating passively with local eddies (Kämpf and Sadrasab 2006).

Environmental Temperature. — The SST, from the summer of 2010 to the summer of 2012, experienced by the tracked individuals had annual fluctuations greater than 18°C and ranged from winter lows of 15.2°C and 13.7°C (2010 and 2011, respectively) to summer highs of 33.7°C , 33.1°C , and 33.0°C (2010–2012, respectively; Fig. 3).

Discussion. — The mean breeding female hawksbill turtle size in Kuwait (73.3 cm) is similar to that of conspecifics elsewhere in the Gulf (70.3 cm; Pilcher et al.

Table 1. Summary data for the 4 nesting hawksbill turtles tracked in Kuwait in 2010.

Turtle	Release location	CCLn-t (cm)	Deployment date (d/mo/yr)	Departure date (d/mo/yr)	Internesting (d)	Minimum clutch frequency	Tracking duration (d)	Maximum displacement (km)
A	Umm Al Maradim	78.5	24/05/2010	11/06/2010	18	2	826	65
B	Umm Al Maradim	69.0	24/05/2010	10/06/2010	17	2	155	170
C	Qaru	70.5	29/05/2010	17/06/2010	19	2	363	80
D	Qaru	77.0	19/06/2010	21/06/2010	2	1	73	45

2014a), which is smaller than those nesting at the most proximate nesting areas outside the Gulf in Oman (81.4 cm; Pilcher et al. 2014a) and elsewhere globally (see Chatting et al. 2018). The smaller size of Gulf turtles has been suggested to be a result of a suboptimal thermal environment compounded by poor food resources (Pilcher et al. 2014a; Chatting et al. 2018).

The modal minimum clutch frequency of 2 nests per individual in Kuwait is fewer than for conspecifics in the Gulf (Pilcher et al. 2014a); however, with a small sample size ($n = 4$) and tracking not taking place from the start of the breeding season, this value is likely lower than the actual population-wide minimum clutch frequency. Turtle

A, which was tracked for 826 d, may have nested in a subsequent year because it approached the known hawksbill nesting sites, but the small size of the nesting islands (< 500 -m diameter), combined with the inaccuracies of Argos locations, means we cannot confirm this. Accurate determination of clutch frequency and remigration intervals (i.e., number of years between breeding seasons), ideally obtained through intensive beach monitoring, is needed to determine realistic estimates for population size and are critical data when considering the low levels of hawksbill nesting present in Kuwait.

All migrations were short (< 150 km) compared with global averages of over 300 km (Hays and Scott 2013) and

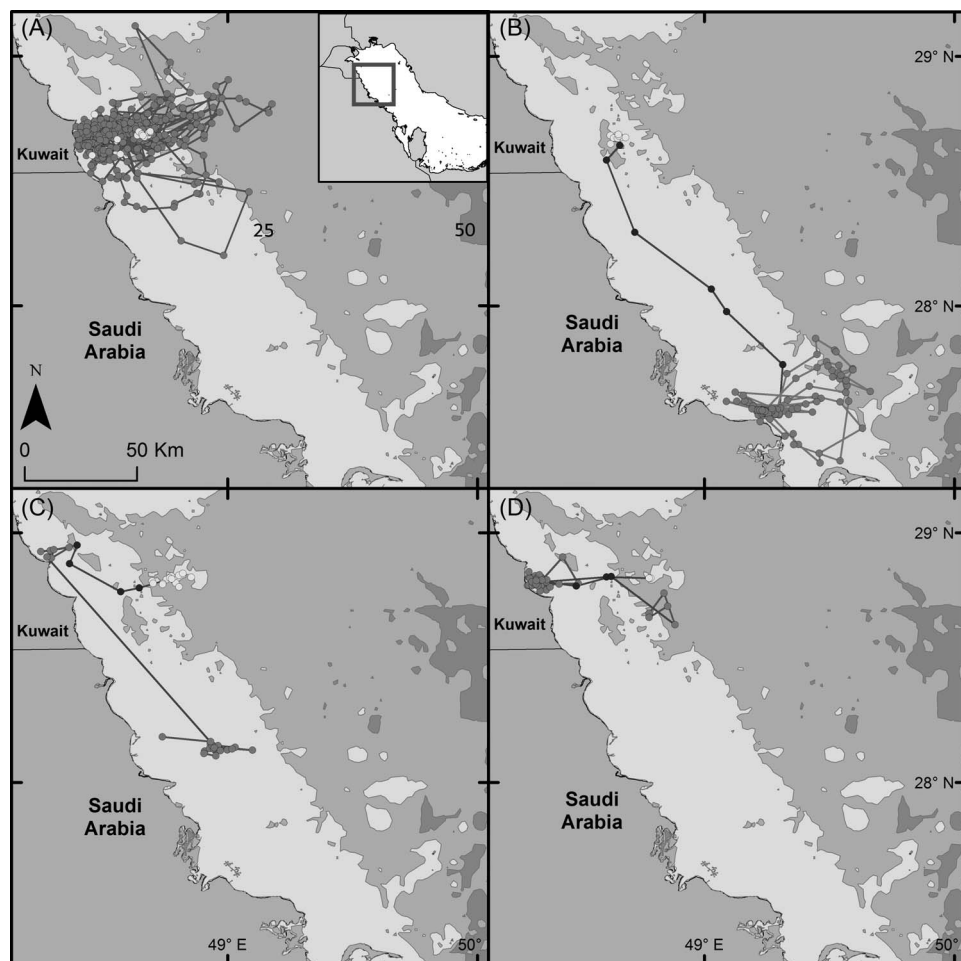


Figure 2. Movements of the 4 hawksbill turtles tracked after nesting in Kuwait in 2010. Panel letters correspond to turtle ID (Table 1). Tracks are defined as pale = internesting, dark = migration, and mid-tones = foraging periods. Sea is shaded for depth with 25- and 50-m isobaths labeled in panel A.

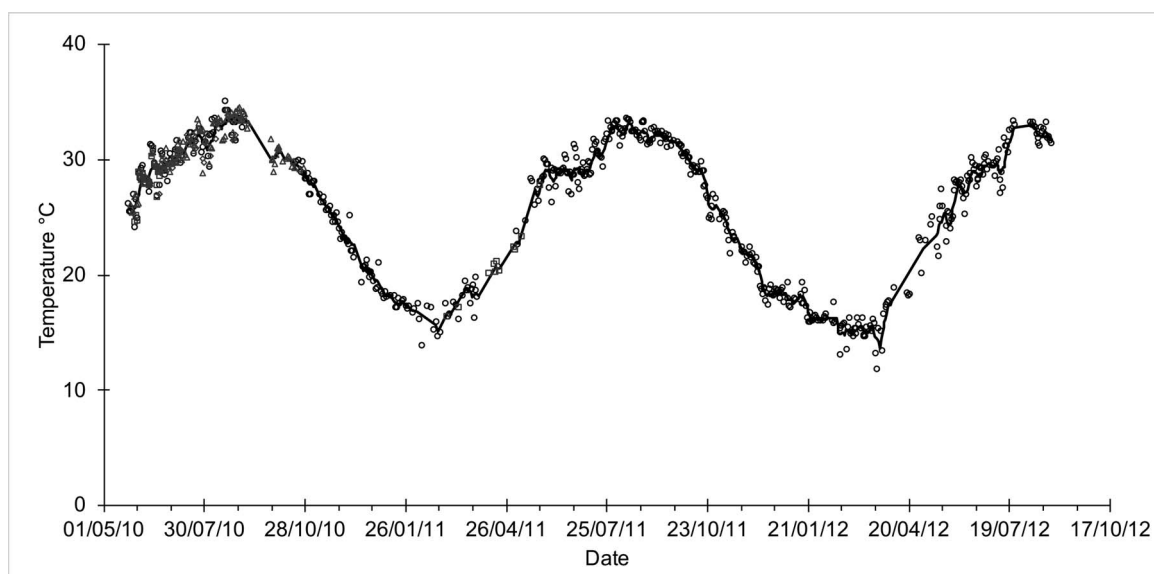


Figure 3. Temporal sea surface temperature (SST) profile experienced by the 4 tracked individuals. Each individual is represented by a different point symbol. Line represents the 7-d moving average of the average daily SST, where at least 4 d contributed temperature values.

directed west and south to shallow (generally < 25-m depth) waters. No turtles migrated north to the vicinity of Failaka Island (Fig. 1), which has been indicated as an important foraging location for green turtles (*Chelonia mydas*) in Kuwait (Rees et al. 2013, 2018). This was to be expected, as green turtles typically feed on algae and sea grasses, whereas hawksbill turtles are generally more carnivorous, often solely spongivorous. Individuals from this study resided in habitats that were broadly similar to others tracked in the Gulf with the first foraging site of turtle C being the same foraging area as the 1 turtle tracked to Kuwait from Qatar (Pilcher et al. 2014a). The remaining 5 general foraging locations described here are newly identified turtle areas, showing no overlap with those from the previous study (Pilcher et al. 2014a), and provide further evidence of the irregular distribution of hawksbills in the region, likely based on the widespread occurrence of small patches of reef (Pilcher et al. 2014a).

Despite summer SSTs over 30°C, peaking at over 33°C, lasting in excess of a month, and turtle tracking periods of 73–826 d covering one or more summer periods, there was no evidence of the turtles undertaking “summer migration loops” to avoid potential thermal stress that was evident in over 83% of turtles tracked after nesting from more southern locations within the Gulf (Pilcher et al. 2014b). This may be an artifact of the low sample size in our study ($n = 4$), but we consider it to be evidence of behavioral plasticity of hawksbills nesting in the Gulf, where spatial distribution and thermal envelope occupancy are driven by the wider expanse of shallow (< 25-m-deep) water in the south of the Gulf (see Fig. 1) and patchy reef habitats proximate to the breeding locations (Pilcher et al. 2014a; Papathanasopoulou and Zogaris 2015).

Conservation Implications. — Given the widespread and diffuse distribution of adult female hawksbill turtles outside the breeding season as evidenced here and the previous study (Pilcher et al. 2014a), it is difficult to assign targeted marine protected areas to spatially restricted hot spots where larger numbers of hawksbill turtles aggregate. Rather, all the shallow seas less than ~ 40-m depth of the southern and western part of the Gulf should be considered putative important hawksbill turtle habitat, where activities that have potential to negatively impact sea turtles need to be monitored and controlled year-round.

Further Regional Research. — Turtles nesting at Ras Al Zour (Fig. 1), which is a confirmed mainland nesting site in Kuwait, are yet to be studied (Rees et al. 2018). In addition, tracking of adult male hawksbill turtles across the region is also lacking. Lack of published migration and habitat use data from the large hawksbill nesting aggregations in Saudi Arabia (Pilcher 1999) further restricts the power of a regional interpretation of hawksbill turtle behavior and needs to be addressed. Completing these studies would fill in the blanks with regard to tracking adult turtles from across the region to determine definitive current high-use important turtle areas.

Furthermore, synthesis of tracking studies, coordinated with benthic habitat studies, should then be integrated into models used to highlight current and potential future habitat suitability following the likely impacts of climate change (Pikesley et al. 2015).

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