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Marine Turtle Conservation Project Final Scientific Report

Arabian Region

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About EWS-WWF

Emirates Wildlife Society (EWS) is a UAE environmental non-governmental organisation, established under the patronage of H.H. Sheikh Hamdan bin Zayed Al Nahyan, Ruler's representative in the Western Region and Chairman of Environment Agency - Abu Dhabi (EAD).

EWS works in association with WWF, one of the world's largest and most respected independent conservation organisations. EWS-WWF has been active in the UAE since 2001 and has implemented several conservation and education projects in the region. EWS-WWF works federally and in the region with offices in Abu Dhabi, Dubai and Fujairah and is governed by a local board of directors.

About the Marine Research Foundation (MRF)

The Marine Research Foundation is non-profit research foundation based in Kota Kinabalu, Malaysia and is incorporated under the Malaysian Trustees Act of 1951. Established to further the understanding of marine ecosystems and their associated diverse flora and fauna in Southeast Asia and other Indo-Pacific sites, the Foundation carries out a number of projects related to biodiversity assessment and conservation, and seeks to provide management-oriented solutions to Government administrations and conservationists.

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Project Partners

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ABBREVIATIONS

ANOVA	Analysis of Variance
AVHRR	Advanced Very High Resolution Radiometer
AVISO	Archiving, Validation and Interpretation of Satellite Oceanographic data
CCL	Curved Carapace Length
CITES	Convention on the International Trade of Endangered Species
DBDBV	Digital Bathymetic Data Base Variable
EAD	Environment Agency - Abu Dhabi
EWS-WWF	Emirates Wildlife Society in association with the World Wide Fund for Nature
GAC	Global Area Coverage
GPS	Global Positioning System
IBAs	Important Bird Areas
ITAs	Important Turtle Areas
IUCN	International Union the Conservation of Nature
MECA	Ministry of Environment and Climate Affairs, Oman
MRF	Marine Research Foundation
NAVOCEANO	United States Naval Oceanographic Office
NESDIS	National Environmental Satellite Data and Information Service
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
OWCP	Ocean Watch - Central Pacific
PTTs	Platform Terminal Transponders
SCENR	Supreme Council for the Environment and Natural Reserves, Qatar
SD	Standard Deviation
SSH	Sea surface height
SST	Sea Surface Temperature
STRP	Sea Turtle Restoration Project
UAE	United Arab Emirates

EXECUTIVE SUMMARY

INTRODUCTION

The Arabian region described in this study comprises the Persian Gulf (also known in some countries as the Arabian Gulf, and hereafter referred to as the Gulf), along with the Gulf of Oman and Arabian Sea. It supports large green turtle populations on Karan and Jana Islands in Saudi Arabia, and at Ras Al Jinz / Ras Al Hadd in Oman. Smaller nesting aggregations are found in Iran and Kuwait, and recently a nest was found in the UAE. There are hawksbill turtle nesting rookeries in Saudi Arabia, Iran, Kuwait, Qatar, Oman and the United Arab Emirates. Masirah Island, Oman supports one of the largest loggerhead rookeries in the world of thousands of nesting females along with hawksbill turtles and a small population of olive ridley turtles (Rees *et al.*, 2012a). Yet, until this study, nothing was known of hawksbill at-sea habitat other than the location of nesting sites and inferences drawn from their spongivorous diet which suggested they inhabited only coral reef habitats.

The Gulf is a unique environment which undergoes extreme water and air temperature fluctuations; as a result this climate has a profound impact on marine species development and distribution. Surface waters typically exceed 30°C for sustained periods and the Gulf can be likened to a natural living laboratory for understanding thermoregulatory behaviour by marine species in the face of climate change and elevated global temperatures. Temperature is important because marine turtles are ectotherms and regulate internal body temperatures through behavioural responses to temperature shifts. Negative influences of changes in climate regimes include habitat availability and nesting success, nesting timing and periodicity, incubation success, gender ratios and hatchling fitness among others. Thus, the ability for turtles (and other species) to respond to temperature shifts may become more relevant in the face of rising global temperatures.

Marine turtles play valuable ecological roles as consumers and prey and they are indirectly linked to seabed and fisheries stability. Marine turtles can be indicator species of the relative health of habitats that support commercial fish and invertebrates (found in seagrass beds, open oceans and coral reefs among others) that are valued by mankind. Marine turtles also have non-consumptive uses such as tourism, education and research.

Marine turtles in the Arabian region have traditionally served as sources of meat and eggs. More recently the harvest of adults is less common but still occurs, and the harvest of eggs on remote islands appears to be on the rise. In addition, many smaller turtles strand on Gulf beaches from cold-stunning in the winter months, and an increasing number of adults are stranding with evidence of drowning in fishing gear. The Gulf is also one of the world's most important exploration and extraction areas for oil and natural gas, and both the Gulf and Gulf of Oman experience among the largest shipping densities in the world via the Straits of Hormuz, posing substantial threats to turtles. On top of this there are commercial, artisanal and recreational fisheries in all countries which further impact turtles. Coastal development is also a major factor that threatens every life stage of turtles in the Gulf; with nesting beaches and foraging reefs being lost to construction and sea grass meadows being dredged. Moreover, coastal modification and noise, light and physical pollution can affect a turtles migratory and nesting behaviours. Given these pressures there is considerable need for focussed conservation strategies which target the full range and extent of turtles' life cycles.

90 HAWKSBILL TURTLES TRACKED

Satellite tracking data for 90 post-nesting female hawksbills (75 tracked by the project and 15 contributed by partners) from nesting sites in Iran, Oman, Qatar and the United Arab Emirates (UAE) have been used to identify key foraging grounds, temporal activity patterns and potential migration bottlenecks. These data and analyses are expected to improve the overall understanding of hawksbill habitat and behaviour in a climate-challenged environment, contribute to our understanding of Important Turtle Areas in the Arabian region, and will support sea turtle conservation-related policy decision-making at national and regional levels.

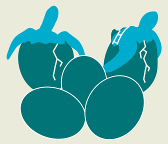
METHODS

Satellite transmitters were attached to the turtles with a fibreglass and resin process. Each turtle was also tagged and measured to provide back-up identification and size data, and tissue samples were collected for genetic analysis. We filtered the data for fixes with a speed of ≤ 5 km/h and excluded implausible data such as landlocked fixes, and positions thousands of kilometres from the previous fix. We selected only one fix per turtle per day, choosing the highest quality fix. Where more than one signal of equal high quality was available, we selected the point closest to midday. All points prior to departure from the nesting site were categorised as internesting. Each approximate two-week block during of internesting behaviour was considered a subsequent nesting event. An increase in travel speeds and assumption of unidirectional travel, until the commencement of foraging, was categorised as migration. Foraging grounds were identified by a reduction in travel rates and a shift from purposeful, unidirectional orientation to short distance movements with random heading changes. Purposeful northeast movements into the middle of the Gulf from July-August, followed by returns in September-October were categorised as summer migrations. We computed home ranges (95% density of foraging location fixes) and core areas (50% of foraging location fixes) to describe the spatial extent of individual foraging grounds and to identify Important Turtle Areas (ITAs).

We also used remotely-sensed physical and biological environmental data to describe the marine environment at foraging grounds and during migration periods: comprising sea surface temperature (SST), sea surface height (SSH) and geostrophic currents, along with surface chlorophyll-a density. We extracted the corresponding environmental and biological data relative to each turtles' position in space (spatially interpolated between grid points at the same resolution as the individual environmental variables) and time, and investigated the relationships between these variables and the turtle location fixes and behavioural state, along with timing of behavioural shifts to explain the behavioural responses.

RESULTS

Given differences in migration and behaviour patterns identified between Gulf, Masirah and Daymaniyat Islands turtles, our analyses typically considered these groups separately. We found a significant difference in curved carapace length between turtles in the Gulf and those from Oman. Turtles in the Gulf averaged 70.3 cm in curved carapace length (CCL), while turtles from Oman were over 10 cm longer, averaging 81.4 cm in CCL.



ARABIAN REGION HAWKSBILLS HAVE THE CAPACITY TO NEST UP TO AT LEAST

6 TIMES

IN A SEASON

The average period after tag deployment and prior to migration among turtles in the Gulf was 20.1 days representing an average of 1.4 nesting cycles with a possible range 0 to 5 nesting events. There were no significant difference in nesting activity by turtles from the Daymaniyat islands or Masirah and the combined average nesting period for turtles from Oman was 11.1 days representing an average of only 0.9 nesting cycles with a possible range 0 to 3 nesting events. Overall our findings indicate Arabian region hawksbills have the capacity to nest up to at least 6 times in a season (the nesting event witnessed by the team and 5 additional ones), but that on average nesting is likely to be closer to 3 events per season, with lower nesting activity by a higher proportion of turtles in Oman than in the Gulf.

Turtles in the Gulf moved primarily in a S or SW direction towards the SW corner of the Gulf shared by the United Arab Emirates, Saudi Arabia and Qatar; although a small proportion of turtles travelled into the Gulf of Salwa (between Qatar and Saudi Arabia) and northwards towards Bahrain, Saudi Arabia and Kuwait. Turtles from the Daymaniyat islands headed SE along the coast of Oman, rounding Ras Al Hadd and heading SW towards foraging sites off the mainland coast near Masirah and further towards the Yemen coastline. Turtles from Masirah, rarely travelled further than 50-80 km to coastal foraging sites off the Oman mainland coast, with the exception of one turtle which travelled 350 km to the SW.

Gulf turtle migrations were short, and completed within an average of just 10.3 days and averaging only 189.4 km. Migrations from the Daymaniyat islands were the longest, averaging 672.6 km over an average 28.6 days. All but two of these reached or passed Masirah island on Oman's south coast, and one migrated into the Gulf via the Straits of Hormuz - the first documented instance of its kind. In contrast, migrations by turtles deployed on Masirah were the shortest of all, averaging only 80.5 km and lasting only an average of 3.95 days. Travel speeds by turtles undertaking migrations were not significantly different between the Gulf, Masirah or the Daymaniyat, with an overall travel speed during migrations of 19.02 km/day.

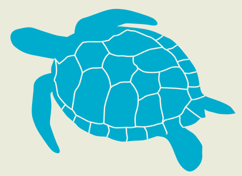
Turtles undertaking summer migration loops generally moved in a north-easterly direction toward deeper sections of the Gulf between July and August, returning in a south-westerly direction to the shallower foraging grounds in September-October. There was a significantly higher travel speed during the summer loop state than preceding or following foraging state, with foraging animals averaging 4.6 km/day and summer loopers averaging 10.9 km/day. The term summer migration loop was derived from the overall timing of the behavioural shift as turtles departed from significantly warmer waters and occupied waters roughly 2°C cooler at the apex of the migration loops, not returning until waters had cooled substantially in the lower south-western reaches of the Gulf.

In the Gulf, turtles occupied discreet and isolated foraging grounds, often returning to the same areas following two-to-three month summer migrations but frequently also moving to new areas. No turtles headed east towards Iran nor, apart from one, the eastern reaches of the UAE, which receive the cleaner waters entering the Gulf from the Sea of Oman. In Oman, turtles from both the Daymaniyat islands and Masirah migrated primarily to waters off Shannah, on the mainland adjacent to Masirah, with an additional few heading to Quwayrah, approximately 250-300 km further.

Travel speeds were slower when foraging (=4.5 km/day), than during migrations (19.02 km/day) or summer loops (10.9 km/day). Home ranges varied in size but overall were relatively small, averaging 48.7 km^2. Most home ranges between 40 and 60 km^2. In contrast, core areas were extremely precise, limited to individual shallow patches and averaging only 3.3 km^2, with the majority of them measuring only 3 to 5 km^2. Gulf home ranges averaged 52.4 km^2 and were significantly larger than home ranges for turtles outside of the Gulf (=39.7 km^2). The core areas reflected this pattern, suggestive of higher quality foraging grounds fronting the Indian Ocean than in the climate-challenged Gulf.

Two turtles provided clues that point to fishery: one of these was deployed off the Daymaniyat islands and headed SE towards Ras Al Hadd. The turtle then reversed course after rounding the headland and headed in a NE direction, crossing the Gulf of Oman. Analysis of tracking data indicated the satellite transmitter was transmitting strongly but that all signals were dry, suggesting the turtle may have been on board a boat. Signals ended half way between Oman and Pakistan. A second turtle left the feeding grounds in the middle of the Gulf suddenly and headed in a NE direction towards Iran. Subsequent tracking data over six months indicated the transmitter was inland, in the vicinity of a town called Koshkonar.

DISCUSSION



GULF TURTLES ARE AMONG THE SMALLEST ADULT TURTLES WORLDWIDE

It is likely that the smaller body sizes of marine turtles in the Gulf are linked to extreme temperature extremes, where surface water temperatures range from a minimum of 16°C during winter months to a maximum of 37°C in the summer. Exposure to temperatures which exceed normal tolerances can lead to a decrease in nutritional uptake and growth, and the cold winter temperatures cause many smaller turtles to strand cold-stunned. Gulf turtles are among the smallest adult turtles worldwide, suggesting growth in Gulf turtles is nutrient-limited.

Data on total reproductive output at a regional level can provide an understanding of population robustness and would allow managers and conservationists to track population performance over time. Interpretation of telemetry data may yield accurate estimates of nesting frequency. In this study, it is shown that turtles from Oman deposited fewer clutches on average than those in the Gulf, and based on detention periods in internesting grounds following transmitter deployment, we estimated turtles could potentially deposit up to five additional clutches (for a total of six), but that the norm was for them to deposit an average of three clutches per season.

Water circulation patterns in the Gulf are not generally strong and average only 0.1 km/h, and we considered these of little consequence to post-nesting migrations of turtles within the Gulf itself. It appears that the smaller body size of hawksbills in the Gulf did little to influence their swimming ability. Average distances travelled during the Gulf migrations were substantially lower than global averages reflecting the relatively small size of the gulf and the lack of emigration to the Gulf of Oman and beyond. In the Gulf, migrations of adult

MAXIMUM MIGRATION DISTANCE APPROACHING

1100km

turtles from the eastern Gulf tended to head southwest and south, opposing eddy currents in the central Gulf. Turtles from northern Qatar did migrate southward and southeastward, in keeping with local currents, but a substantial number also moved north and northwest from nesting grounds, opposing local currents. Three turtles showed tendencies to enter the Gulf of Salwa, migrating between Qatar and Bahrain and outward again. In light of deliberations on the creation of a causeway to link the two countries, we consider this an area of conservation concern, creating a migratory bottleneck between the two landmasses.

It appears the Somali current, of the Arabian Sea, did not impede the purposeful swimming registered for Oman's turtles, even given the hawksbill's general perception as the 'more sedentary' of sea turtle species. Migration distances for turtles departing the Daymaniyat islands were more than twice the global average for adult hawksbills with a maximum migration distance approaching 1100 km. Turtles departing Masirah covered significantly shorter migration distances than global averages, with migrations averaging only 80.5 km. However, all but one of these turtles headed to the nearby Omani mainland, with an average displacement of <30 km, far smaller than the global average of 327 km. We consider the bottleneck at Ras Al Hadd a major concern for Oman turtles given the extensive artisanal and commercial fishing in the area. All except for one turtle from the Daymaniyat Islands rounded the Ras (cape) and headed SW to Masirah and beyond, and we suggest this area be considered as a critical pathway for turtles in the region. Similarly in Oman we suggest the area between the southern tip of Masirah island and Shannah on the mainland to be an important migratory pathway and foraging ground.

Our results indicate Gulf hawksbills employ thermoregulatory responses which take them out of high temperature and potentially physiology-threatening conditions. Sea surface temperatures during the summer averaged 33.5°C and peaked at 34.9°C. During these elongated periods of elevated temperatures (June-August) the turtles temporarily migrated an average of 70 km to deeper and cooler waters at northern latitudes, returning after 2-3 months (September-October) back to original feeding grounds. Temperature differential (Δt) between foraging and summer loop habitats was significantly different and approximated -2°C. Turtles undertaking summer migration loops generally moved in a north-easterly direction toward deeper water, returning in a south-westerly direction to the shallower foraging grounds. Swim speeds were significantly higher and orientation was less omnidirectional during the migrations than when foraging. The outbound migrations were significantly inversely correlated with temperature, but were not linked to chlorophyll-a, geostrohphic currents or sea surface height. The thermoregulatory behaviour was not detected in turtles outside of the Gulf and is believed to be a consequence of the more temperate waters of the Indian Ocean, where the narrow continental shelf along the Oman coast brings the effects of cold-water upwelling close to shore.

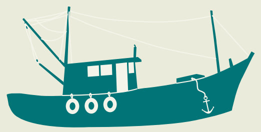
GULF TURTLES SPENT

70%

OF THE THEIR TIME FORAGING

Turtles in the Gulf spent some 70% of their time on foraging grounds, and Omani turtles spent upwards of 83% of their time in foraging areas. The difference in these two time allocations is the result of Gulf turtles undertaking summer migrations to escape higher surface water temperatures during summer months, during which we believe they were not feeding. The foraging habitats were spread over vast areas but at the individual turtle level typically ranged over only 40-60 km^2 with core areas of only 3-5 km^2. Home ranges and core areas for Omani turtles were substantially smaller than those for Gulf turtles, suggesting Oman turtles have access to higher quality foraging areas than those turtles living in the climate-challenged Gulf, with a decreased requirement for wide-spread foraging movement. Ground-truthing suggests that these areas may be limited to small reef mounds only 100s of meters across. In the SW corner of the Gulf foraging grounds were distributed across ~20,000 km^2 between Abu Dhabi in the UAE, a small parcel of Saudi Arabian territorial seas, and the southern reaches of Qatar. In Oman the foraging habitats were spread along >500 km of coastline, but given the steep deepwater drop-off close to the Omani coastline their habitats were restricted to a narrow coastal belt.

Contrary to our earlier expectations that Gulf hawksbills would inhabit clear-cut areas that may be demarcated for some level of protection, the widespread dispersal of hawksbills across the SW Gulf may limit the habitat protection options available to managers. Hawksbill foraging habitats are predominantly located in shallow waters where overlap with commercial shipping might be less of an issue, but this is where most traditional fisheries take place. Industrial/urban development of shallow water areas should be curtailed to maximise foraging habitats for hawksbills, and fishery activities should be evaluated for their impact to hawksbills, with a view to introducing regulations and conservation programmes which promote turtle survival. In Oman the identification of Important Turtle Areas was substantially clearer, with the identification of Shannah and Quwayrah as being key foraging habitats, and the waters off Ras Al Hadd – indeed the 20 km band along the shores between the Daymaniyat Island, Muscat and Masirah Island – constituting an important conservation bottleneck for hawksbill turtles.



FISHERY-RELATED MORTALITY IS A CONSERVATION CONCERN IN THE REGION

Small-scale artisanal fisheries have the potential to inflict severe negative impacts on in marine turtles. In this study satellite tracking revealed the mortality of two out of 90 turtles, suggesting that fishery-related mortality is a conservation concern in the region. Importantly, given the vast dispersal area for hawksbills and other turtle species in the region, it is likely that conservation will be best aided by fishery management measures, and a critical look at impacts from fisheries at a regional level is warranted.

The results of our work may be used by government and conservation agencies in spatial formats compatible with Global Information Systems enabling risk assessments for turtles in the face of urban and industrial development including oil and gas industries, climate change, fishery pressure, and shipping activities. These risk assessments will further highlight the overlaps between important turtle habitat and the varied threats in the Arabian region and provide a pathway for prioritising Important Turtle Areas for dedicated conservation and management action.

The hawksbill turtle *(Eretmochelys imbricata)* is listed as Critically Endangered globally on the IUCN Red List.

1.1 MARINE TURTLE BIOLOGY AND CONSERVATION NEEDS

Marine turtles have roamed the planet's oceans since the late Triassic, and have remained relatively unchanged since that time. Indeed, much of the planet itself remained evolutionarily relatively unchanged, save for natural physical and biological processes such as sea level rise and fall, up until the last two millennia, if not the last two centuries. But during this time mankind has had a considerable impact on the globe's physical appearance and climate…

From free-roaming and numerous as recently as two hundred years ago to endangered and critically endangered today, marine turtles have fallen victim to mankind's industrialisation and human population growth. Mechanised fisheries, industrial development, expansion of the human footprint, habitat loss and degradation, and climate change have driven turtles to a precarious state.

Due to their elusive at-sea nature, the plight of marine turtles remained unknown until the pioneering work of the late Archie Carr in the Southern US and Central Americas back in the 1960s and 1970s, and that of his peers around the world. Since that time, and with the growth of the community of sea turtle researchers, biologists and conservationists, and more recently of a concerned private sector, much has been done to help populations that were in decline and to protect habitats crucial to their long-term survival. The critical biological adaptations peculiar to marine turtles, such as the migrations they undertake to nest, the long period between emerging as a hatchling and returning as sexually mature adults, the cues that help orient hatchlings seaward, and the variety of habitats they require to advance through life, all have contributed to create conservation issues that today are tackled by a host of research and management programmes.

Turtles spend almost all their life cycle in the ocean. They are solitary cold-blooded reptiles which need to surface to breathe, and only emerge on land to nest (females) and very occasionally to bask (both males and females – although basking has not been recorded in the Gulf region, likely given the extreme high temperatures). The life cycle of sea turtles is similar across species and can be described generically (Figure 1). In general, turtles migrate from distant feeding grounds to different nesting areas and once the males and females arrive, they mate during a period of one to two months, although individual females are only receptive for two to three weeks. Males mate with several females, and females mate with several males. Fertilisation of eggs is often by multiple males, likely as an evolutionary tactic to maximise genetic diversity. After mating it generally takes two to four weeks for a female to lay the first clutch of eggs, and after this the females may return two to eight more times in the same season to nest. Nests typically contain 80-120 eggs depending on species, which take approximately 45-65 days to incubate, and invariably hatch after dark, when the sand surface cools (so the hatchlings to not suffer from the heat of the sun on emergence).

Hatchling sex ratios are correlated to nest temperatures, whereby warmer nests produce higher proportions of female hatchlings. Temperatures during incubation are often a function of sand colour, whereby nests in darker sands incubate at higher temperatures and produce more females. The hatchlings dig through the sand for two or three days before emerging, then crawl down the beach and head in an offshore direction, mostly using light to reach the shore, then waves through the nearshore waters and finally magnetic fields for guidance and orientation as they reach offshore areas. They swim for one to two days in what is known as a 'swimming frenzy' to get as far offshore as possible and after this they generally float on the surface among convergence zones and weed lines for several years until they recruit as small 20-40 cm juveniles from oceanic waters to nearshore shallow feeding areas. They typically remain at one or multiple feeding grounds for five to ten or more years until they reach sexual maturity, and undertake their first migration to the mating and nesting areas, whereupon the cycle is repeated.

A common feature of the reproductive biology of all marine turtle species is the use of beach habitat for nesting. Female marine turtles emerge from the water, generally at night, and move up the shoreline to select a nesting location. Most females do not nest in consecutive years. However, female marine turtles usually deposit several clutches of eggs per year. Sea turtles generally demonstrate fidelity to a nesting beach and return to nest on their natal beach with some degree of precision. The process by which turtles select nesting sites along a beach has not been clarified; however light regime is considered to have a significant impact on the emergence of female marine turtles from the ocean. Marine turtles may also emerge from the water and then return without attempting to excavate a nest or lay eggs – a phenomenon often referred to as a "false crawl".

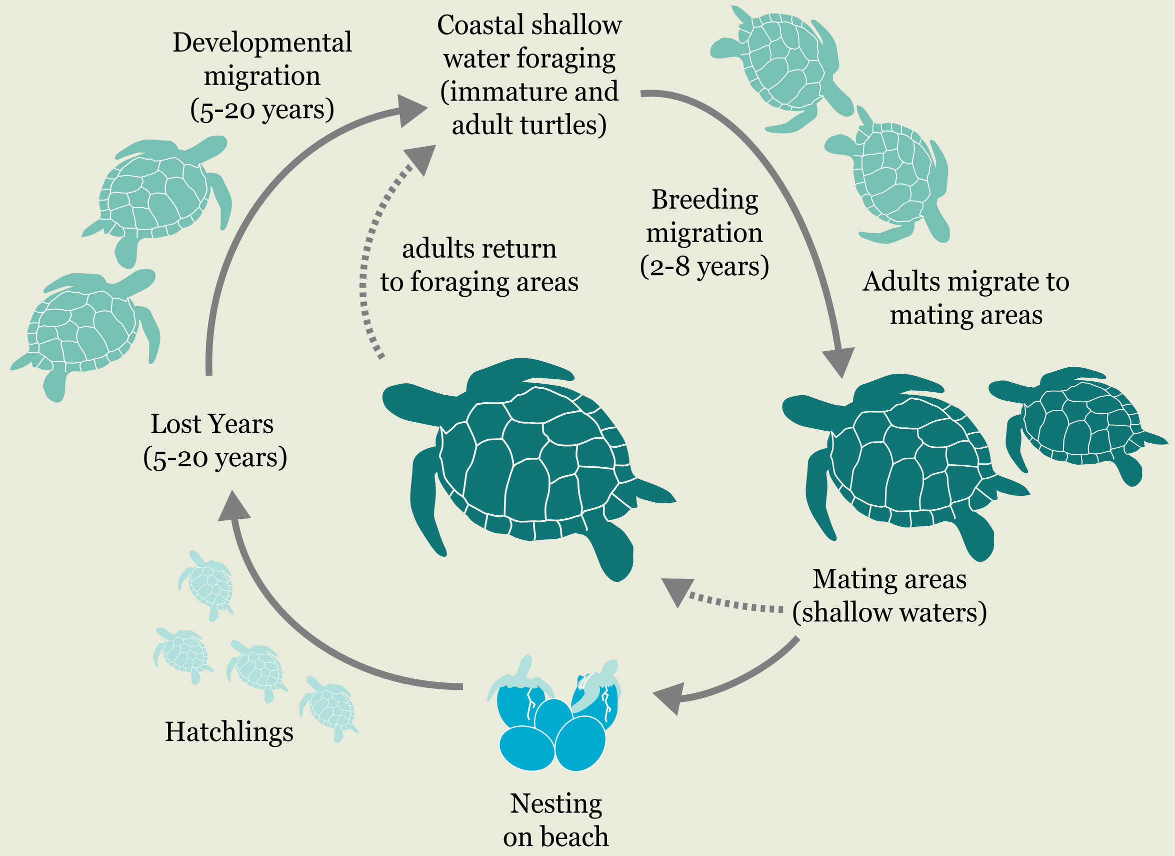


Figure 1: Generalised life cycle of sea turtles

When eggs hatch and hatchlings emerge, lighting cues have been identified as critical for hatchlings to move from the beach to the ocean – a behaviour known as 'sea-finding'. In simple terms, where there are no anthropogenic light sources hatchlings move from away from the dark silhouetted shoreline towards the

brighter ocean horizon. Changes to the lighting regime can affect a hatchling's attempts to find water. Lights at a nesting beach can result in turtle hatchlings heading inland rather than into the ocean, with subsequent mortality. In areas where man-made light sources are highly visible, emerging hatchlings have been documented to become disoriented (loss of bearings) and misoriented (incorrect orientation) thus travel inland rather than seaward. The disorientation or misorientation can prove to be fatal due to increased exposure to predators, entrapment in vegetation or debris and dehydration. Similarly, nesting turtles can become mis- and disoriented once they have nested and are sensitive to disturbances i.e. human presence, noise produced through construction activities could lead to an increase in non-nesting emergences.

Adult female turtles appear to be pre-conditioned to emerge on darker, more protected beaches than those in front of major urban and industrial areas. It is likely this is an evolutionary response whereby those eggs deposited on darker, more protected beaches have a higher likelihood of developing into hatchlings that successfully find the ocean, and migrate offshore. Once hatchlings enter the surf line they begin a general offshore migration during which they face a number of additional obstacles, such as currents, waves and predators. A hatchling's ability to move offshore quickly greatly increases its chances of survival, as predation rate decreases with depth and distance from land. Thus, a female's preponderance to nest on beaches free of light pollution are likely evolutionary responses to selectivity for light attenuation.

Brightness in this context encompasses both wavelength and intensity. Marine turtles do not perceive light in the same way that we humans do. Generally, they respond to short wavelength light (blue/green) including wavelengths that we cannot see (ultraviolet light) but only weakly respond to light that humans see well (red light). The exact details of the response of hatchlings to light regime differs between species. For example, the flatback turtle responds much more strongly to longer wavelength light (red light) than the other species which may be a result of the reduced light penetration in inshore habitats where this species resides.

For each marine turtle species there are several distinct populations based on genetic distinctness, and these are variously referred to as management units, stocks, ecologically significant units, or regional management units. Both species of turtles nesting in the Gulf are known to be genetically distinct from their cousins outside of the Gulf. There is limited gene flow between nesting areas, and replenishment of a population is negligible or extremely slow given the lack of movement of turtles amongst management units. That is, if hawksbill turtles were to be extirpated from Gulf waters, there would be little or no replenishment form outside populations.

1.2 ECOLOGICAL ROLE

Sea turtles play valuable ecological roles in marine ecosystems as consumers and prey among other roles, and they are indirectly linked to seabed and fisheries stability. They function as key individuals in a number of habitats, and can be indicator species of the relative health of habitats that have a tangible value to society. These habitats support commercial fish and invertebrates (found in seagrass beds, open oceans and coral reefs, among others) that are valued by mankind. For example, green turtles crop seagrasses and maintain the health of these important habitats. Seagrass beds can also be developmental grounds for shrimp and other larvae, which are the building blocks of economically-valuable shrimp and fin-fisheries industries. Today, turtles also have non-consumptive uses such as tourism, education and research.

1.3 HAWKSBILL BIOGEOGRAPHY

While hawksbill turtles are globally distributed, they typically occupy a relatively narrow water temperature range common to their principal habitat in the tropics, where surface water temperatures typically range from 22 to 30°C and remain relatively constant throughout the year. While the latitudinal limits of hawksbill habitats frequently fall below the lower thermal range - for example in the Indian Ocean off Oman temperatures can drop to 20-22°C when subjected to oceanic upwellings (Ross 1981) - they rarely exceed the upper thermal range for extended periods. Apart from Torres Straits (Whiting 2000) where shallow tidal areas can reach 32°C, no other hawksbill habitat in the world experiences the months-long extreme high SSTs of the Gulf.

This brief look at temperature ranges is important because hawksbill turtles are ectotherms - that is they are cold-blooded - and as with all sea turtles, broadly regulate internal body temperatures through behavioural responses to temperature shifts. The ability for turtles to respond to temperature shifts may become even more relevant in the face of rising global temperatures. There is a substantial body of work which outlines the potential impacts of climate change on turtles (Hamann *et al.* 2007, Hawkes *et al.* 2007, Witt *et al.* 2010, Fuentes et al 2013, Pike 2013) which documents the negative influences of changes in climate regimes on habitat availability and nesting success, nesting timing and periodicity, incubation success, gender ratios and hatchling fitness, among others. Given the slow water circulation in the Gulf and high ambient air and water temperatures, which exceed that found in other hawksbill turtle habitats throughout their range, this marine habitat could be likened to a living laboratory for how turtles might behave in the face of climate change and rising temperatures linked to climate change elsewhere on the planet.

1.4 THREATS

Being long-lived and of late maturation, sea turtles face a multitude of threats over long periods of time. These threats include mortality in mechanised and artisanal fisheries, egg and turtle consumption, and habitat degradation and loss. And while sea turtles are evolutionarily prepared to suffer high mortality rates in the early life stages (lots of eggs and young hatchlings become food for other species), their large adults have a substantially high reproductive and population maintenance value, and losing this population segment could spell disaster for a population. That is, the loss of a small proportion of eggs or hatchlings may be compensated by their demography, but the loss of older animals can have substantial negative effects on population size, because fewer animals are available to reproduce and maintain the stock size. Compounding this, because turtles comprise distinct genetic stocks (or management units) which precludes substantial interaction of stocks and restricts gene flow, if a turtle stock declines in one place, there is little likelihood it will be replaced by turtles from another stock nearby. In practice this means that turtle populations that have been decimated are not about to rebound through massive immigration from outside populations. To complicate matters, hatchlings disperse into open ocean areas, adult turtles migrate great distances between foraging and nesting habitats, and juveniles and adults can occupy multiple foraging grounds at different stages of their life cycle, making sea turtle conservation a truly international process.

Hawksbill sea turtles are Critically Endangered globally and are threatened with extinction, having been heavily over-harvested by mankind throughout their range. Globally, sea turtles have provided food at a subsistence level to fishermen and coastal dwellers since time immemorial. Turtles have also been used traditionally for their shell, fat and meat, and their eggs have fed hungry families dependent on the bounty of the sea. But with increased coastal use and industrialisation, and the advent of outboard motors, refrigeration and rapid transport to major urban areas, the loss of turtles and their eggs has reached a level from which populations are struggling to recover. Turtle eggs, which used to be collected on an occasional, irregular basis, are now collected nearly every single time a nesting female emerges on the beach. The increased development of the petrochemical industries has also resulted in severe habitat loss and alteration, and measures are urgently needed to safeguard the few remaining sites.

1.5 CONSERVATION & MANAGEMENT

Conservation programmes in the region race to stem the tide of decline and re-establish viable nesting and feeding populations of these magnificent ancient mariners of our seas. Nesting beaches are protected in most countries, and laws have been enacted and enforced in several locations which protect turtles and their products. Education and awareness programmes are spreading across the region, and today a few previously-declining turtle populations are again on the rise. But knowing about nesting turtles is simply not enough. Understanding the location of critical turtle habitats and the times turtles spend at these is essential for the design of effective and efficient conservation programmes. These data are needed to inform management agencies and conservation practices in a region home to one of the most climate-challenged marine habitats on the planet, subject also to immense urban expansion, shipping and petrochemical industry pressures, and which supports large nesting and foraging populations or endangered sea turtles.

1.6 OCEANOGRAPHIC SETTING

The Arabian region covered by the project includes the Persian Gulf, which is also known as the Arabian Gulf (and hereafter referred to simply as the Gulf), the Gulf of Oman and the Arabian Sea.

1.6a The Gulf

The Gulf is a unique environment which undergoes extreme water and air temperature fluctuations. The sea water circulation pattern is slow and counter-clockwise, with waters entering the Gulf and moving up the coast of Iran, then down the coasts of Kuwait, Saudi Arabia and Qatar, and eastward along shallow waters of the United Arab Emirates (Figure 2). Surface water temperatures range from a minimum of 16°C during winter months to a maximum of 37°C in the summer, and air temperatures range from 0°C in winter months to greater than 50°C in the summer.

Given these temperature extremes, turtles nest during a short summer period (April through July). Beaches are unvegetated and provide no shade relief for incubating eggs. Given that gender determination in sea turtles is controlled by temperature, a balance of males and females is produced through the temporal spread in nest deposition. That is, nests deposited early in the season when temperatures are cooler likely produce more males, and nests laid later in the season and which incubate in July and August likely produce most of the females. Limited experiments in the region so far indicate that eggs deposited in April incubate at about 24.5°C while nests deposited in May might experience incubation temperatures reaching 33.5°C (SCENR 2006). Air and surface sea water temperatures are at or above the known tolerance extremes of all species of marine turtle (Miller 1997) and above the normal range for hawksbill habitats globally, yet Arabian hawksbill populations appear to thrive.

1.6b Gulf of Oman & Arabian Sea

Outside of the Gulf, the study region spans the Gulf of Oman and the northwestern potion of the Arabian Sea. The Gulf of Oman is a semi-enclosed basin where the depth ranges from ~100 m to ~3000 m, and connects the Arabian Sea with the Strait of Hormuz, which then runs northwards into to the Gulf. The Oman Gulf is mostly influenced by monsoon winds - winter monsoon winds blow to the Southwest from December to April - experiencing high evaporation rates, along with high surface sea temperatures and salinity.

Water circulation in the Arabian Sea is also strongly influenced by the monsoon winds and intense air-sea heat fluxes. During the summer monsoon, upwelling occurs on the Southern coast of Oman, near Ras al Madrakah - Ras As Sharbatat, bringing cooler waters and increasing coastal productivity (Figure 2). Water temperatures vary from 20 to 37°C in the Gulf of Oman, and from 17 to 37°C in the northern Arabian Sea. The rich productivity of the northwest Indian Ocean linked to the monsoonal upwellings results in substantially different environmental conditions for hawksbills, which live in nutrient-rich waters and grow to be substantially larger than their counterparts which live amongst the temperature-challenged environments of the Gulf.

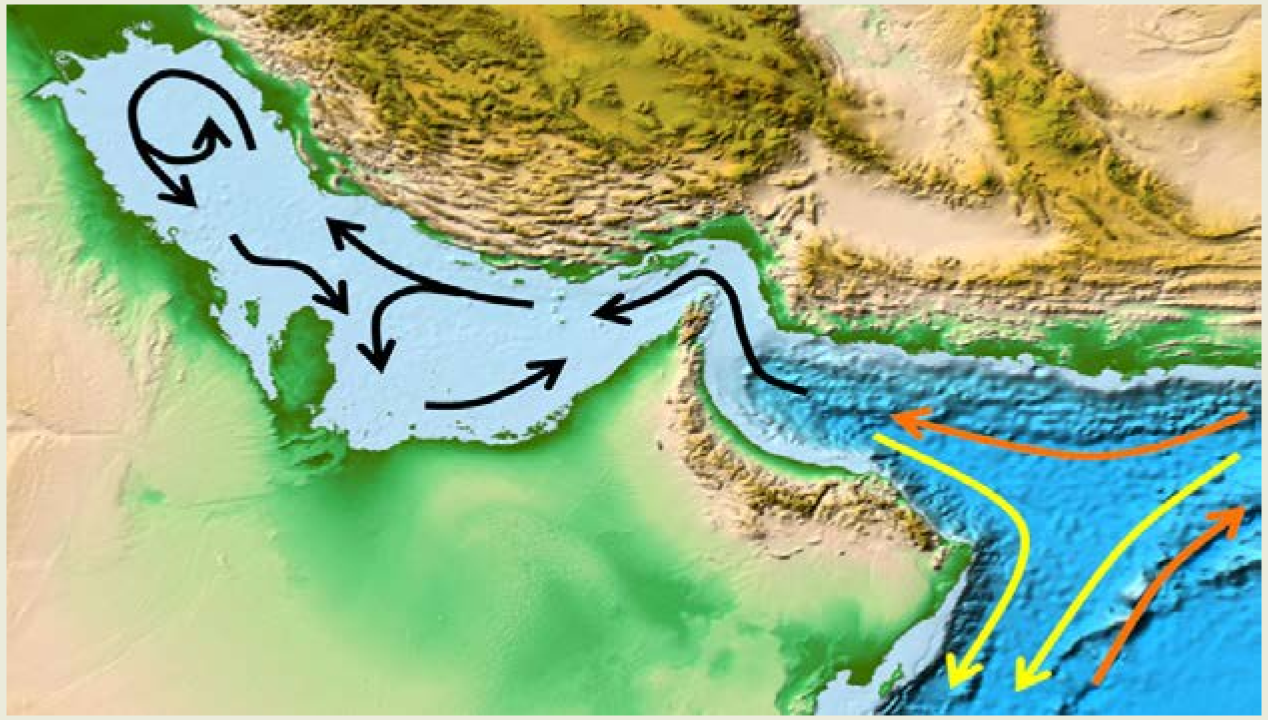


Figure 2: Generalised ocean circulation pattern for the Arabian region. Black arrows represent generic Gulf water movements. Yellow arrows depict winter monsoon flows while orange arrows represent the summer monsoon.

1.7 LOCAL CONSERVATION STATUS OF MARINE TURTLES

The Arabian region supports relatively unknown but substantial sea turtle populations, with greens and hawksbills found to be most abundant within the Gulf and loggerheads and greens dominating the Gulf of Oman and Arabian Sea. While the scientific community remains largely unaware of what the region holds, limited scientific publications reveal populations in each country.

Saudi Arabia is found to host a large annual green turtle population of about 1000 nesting females on Karan and Jana Islands (Al-Merghani *et al.* 2000, Miller 1989, Pilcher 1999). Greens also nest in small numbers on some Kuwaiti islands (Meakins & Al-Mohanna 2004) and along the Iranian coast within and without the Gulf (Mobaraki 2004a, 2004b). The UAE and Qatar are home to numbers of foraging green turtles although no significant nesting populations (Al Suweidi *et al.*, 2012; Rees *et al.*, 2013). Oman plays host to the largest green turtle rookery in the region of around 5000 females/year nests at Ras al Hadd – Ras Al Jinz (Ross & Barwani 1982).

Hawksbills nest at five key sites in Qatar, with the two most studied including Fuwairit and Ras Laffan City (Tayab & Quinton 2002, SCENR 2006) and in the United Arab Emirates they have been found to nest on numerous small islands (EAD 2007; Pilcher *et al.*, 2014). Hawksbills also nest at several key sites along the coast of Iran, likely numbering several thousand nesting females/year (Mobaraki, 2004). Outside of the Gulf, hawksbills also nest at the Daymaniyat islands (Salm *et al.*, 1993) and on Masirah Island in Oman (Ross 1981, Ross & Barwani 1982).

Masirah Island supports a large loggerhead rookery too, once believed to support tens of thousands of nesting females (Ross & Barwani 1982, MECA unpublished data). Loggerhead turtles are infrequent visitors inside the Gulf proper – although they have been recorded entering the Gulf via satellite tracking studies - and are not known to nest at any of the known Gulf rookeries.

Olive ridley turtles are also known to nest on Masirah Island in low numbers (Rees & Baker, 2006) as well as in a few locations along the southern coast of Iran (Mobaraki, 2004a). Leatherback turtles are only considered infrequent visitors to the region.


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Figure 3: Hawksbill turtle *(Eretmochelys imbricata)* nesting in Qatar.

This project tracked hawksbill turtles (Figure 3) from nesting sites in the Arabian region to elucidate post-nesting migration behaviour.

However, while much is known of nesting turtles, practically nothing – until now – was known of where these turtles spend their time at sea. Whether Gulf turtles leave the Gulf, or if there is a substantial movement of turtles through the Straits of Hormuz, even where they spend their time when not in the vicinity of nesting beaches; the picture is not clear. Filling in these knowledge gaps is crucial to ensure turtle survival in the region, because turtles spend most of their time at sea.

Conservation of turtles requires protection not only at nesting grounds but also at their foraging and development grounds, and this project was designed to answer the lack of information on foraging areas and to identify Important Turtle Areas (ITAs) in order to focus conservation-related management interventions.

1.8 PROJECT RATIONALE

Given these biological characteristics and the myriad threats they face, conservation of sea turtles is a massive challenge. The challenge lies in balancing developmental needs with conservation requirements, and a grounded knowledge of the biology and habitat requirements of the species is considered a prerequisite for sound decision-making by developers and policy-makers. Conserving sea turtles requires knowing about population trends, threats, and overlaps between threats and turtle habitats. Nesting populations in the region have, for the most part, been well documented and are periodically monitored by government agencies and NGOs. Less well-understood however is the location of foraging grounds and dispersal patterns / behaviour of turtles that use these nesting sites. Recent work in Oman tracking loggerhead and olive ridley turtles (Rees et al 2008, 2010) has documented some use of the Oman Sea and Indian Ocean as foraging habitat, with animals rarely moving far offshore. Recaptures of a handful of green turtles tagged in Oman and in Saudi Arabia have been documented at feeding grounds off Ras Al Khaimah, at the eastern tip of the UAE (EAD 2007), and a handful of tag returns are known of loggerheads and greens from Masirah island in Oman reaching Yemen and Eritrea. Around 10% of satellite tracked loggerheads from Masirah migrated into the Gulf and their tracks invariably ended around north Qatar / Bahrain (MECA, unpublished data). But until this study, nothing was known of hawksbill habitat other than the location of nesting sites and inferences drawn from the location of coral reef habitats, a reasonable assumption given their spongivorous diet – hawksbills subsist primarily on a diet of glass. (Meylan 1988).

While much is known of Arabian region nesting turtles, and substantial investment has been made to safeguard important nesting areas (e.g. in Oman, Qatar and in Iran most sites are protected as National Parks or Reserves, or by proxy by being located within restricted access areas), little has been done to address the ocean habitats, where turtles spend the vast majority of their time. To develop effective and efficient targeted conservation programmes which will protect turtles in the marine environment, it is necessary to determine habitat use patterns and turtle behaviour once they depart from their nesting beaches, and make this information available to management and conservation agencies. This project aimed to address the lack of information on foraging areas and to identify Important Turtle Areas (ITAs), and focus conservation-related management interventions to ensure long-term sea turtle survival.

1.9 PROJECT PARTNERS

This project was initiated as a partnership between the Emirates Wildlife Society – Worldwide Fund for Nature (EWS-WWF) based in the UAE, and the Marine Research Foundation (MRF) based in Malaysia.

EWS-WWF assumed full responsibility for project financing, logistics,communications and overall project coordination, while MRF contributed the scientific expertise. EWS-WWF and MRF worked with numerous partners in the region to ensure the widest possible collaboration and participation, sharing of knowledge and skills, and use of the best available science and local knowledge. In each country, the project worked collaboratively with government agencies and NGOs to deliver on key objectives. The partners in each of the countries were:

Iran
- Wildlife and Aquatic Affairs Bureau of the Department of Environment

Oman
- Ministry of Environment and Climate Affairs
- Environment Society of Oman

Qatar
- Ministry of Environment
- Ras Laffan Industrial City
- Qatar University

UAE
- Environment Agency - Abu Dhabi
- Emirates Marine Environmental Group
- Environment & Protected Areas Authority, Sharjah

The strengths brought to the project via the government linkages can not be overstated: these agencies provided the legal framework within which to operate, and are the agencies to implement conclusions and recommendations emerging from this work. External non-government institutions provided logistical support, access to remote field sites, local expertise, and all forms of in-kind assistance.

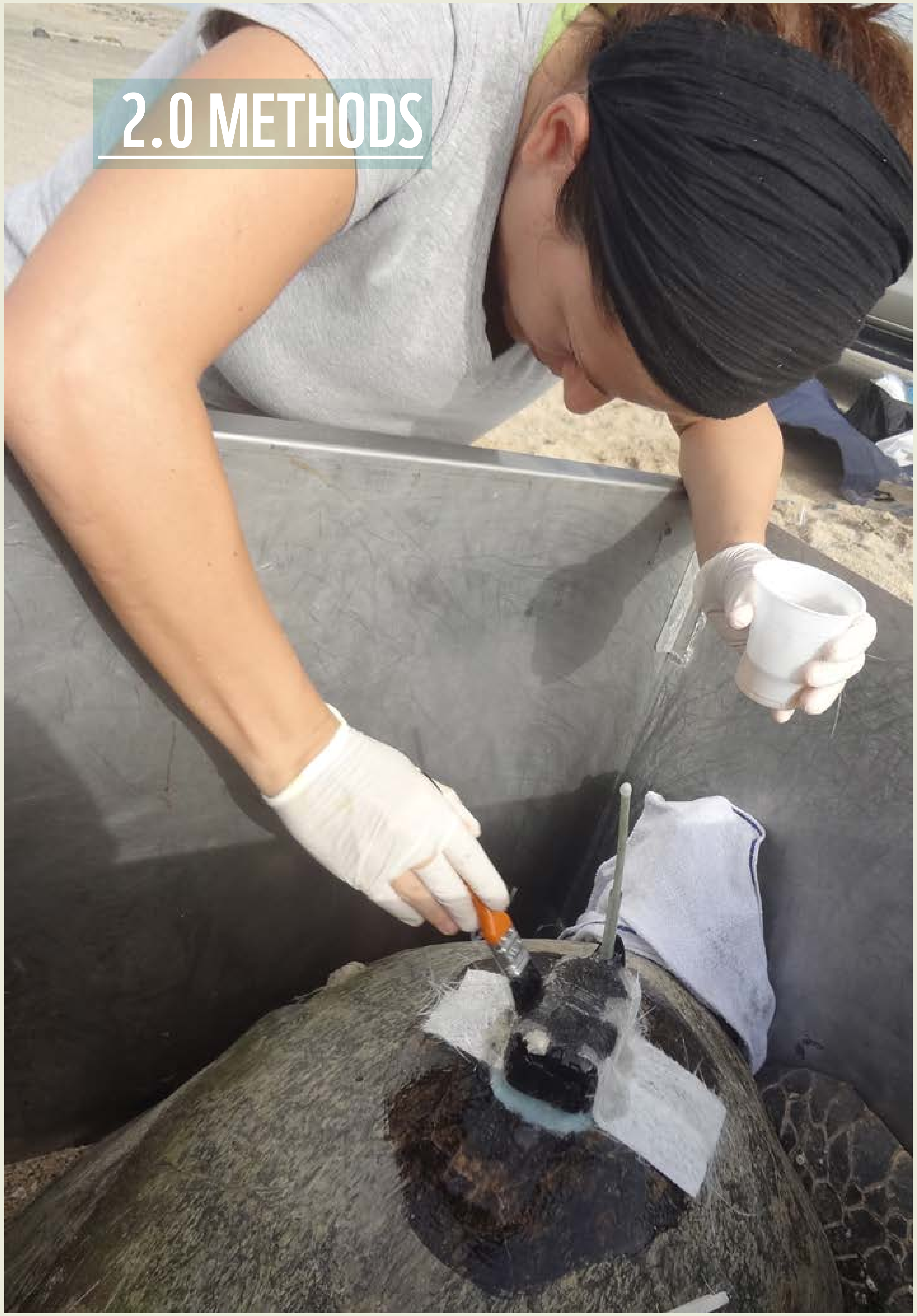
1.10 PROJECT SCOPE & OBJECTIVES

Overall, this project aimed to understand the biological and developmental needs of hawksbill turtle populations, which are heavily dependant on the understanding of the extent of habitat use and distribution. The project also aimed to raise awareness to their plight. As stated in the original project proposal:

"The goal of the project is to implement a comprehensive awareness and research programme using the latest in technology and science - satellite tracking - to promote conservation of marine turtles of the region. The project will involve numerous stakeholders, and will combine scientific research and monitoring with environment awareness centred on marine turtle protection to bring about regional change – a positive change resulting in long-term conservation of marine turtles."

To accomplish this, the project aimed to track seventy five post nesting female hawksbill turtles from various sites in the Arabian region and elucidate port-nesting behaviour and habitat use. The tracks would provide data on turtle movements while the publicity surrounding the project would raise regional awareness of the importance of sea turtles in marine ecosystems. The original project design entailed tracking 25 turtles per year during 2010, 2011 and 2012. By spreading the effort out over several years we are better able to determine differences in behaviour with differences in climatic conditions, release sites, and other environmental factors. Average data sets were longer than one year and several units were still operating in February 2014! We report on these data sets, combined with an additional ten tracks from 2011 and 2012 provided by collaborators at Qatar University, two additional data sets from 1999 provided by the Environment Agency of Abu Dhabi, and an additional two data sets from 2007 and one from 2011 shared by the Environment Society of Oman and the Ministry of Environment and Climate Affairs in Oman.

2.0 METHODS



Satelitte transmitters are attached to the turtle's carapace to be able to track the movements of the animal post-release.

2.1 PROJECT LOCATIONS

To maximise data on post-nesting behaviour we deployed PTTs as early as possible in the nesting season at various nesting locations spread across the region (Figure 4). These sites (Table I) were selected based on previous published literature to allow for differing migration patterns and to determine if turtles from different nesting sites used the same or differing feeding sites.

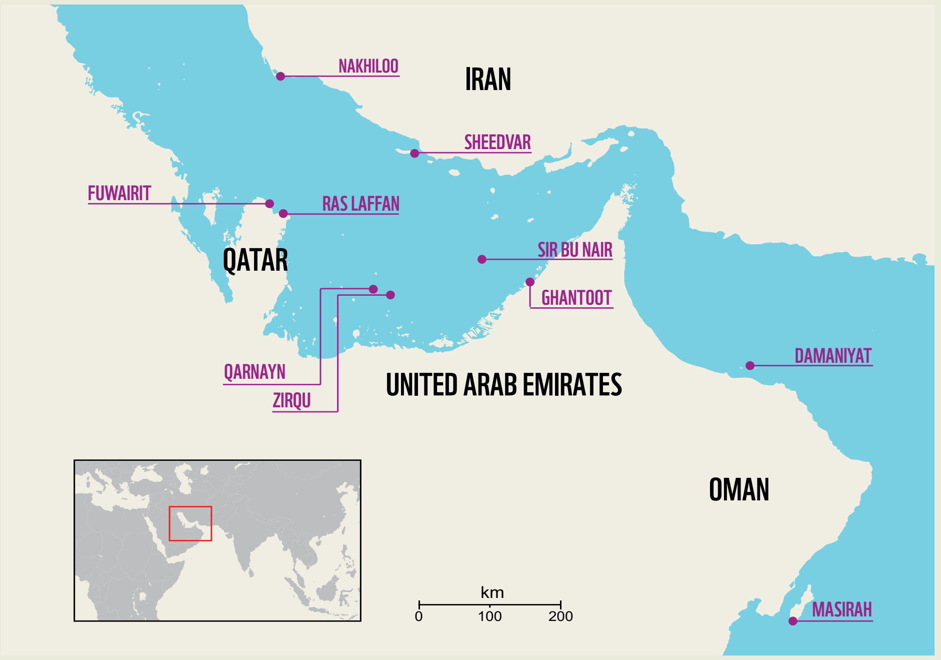


Figure 4: Rookeries from which transmitters were deployed between 2010 and 2012.

Table I: Summary of PTT deployment dates and locations, including those of project partners.

Country	Location	Latitude	Longitude	1999	2007	2010	2011	2012
Iran	Sheedvar	26.794	53.420			5		
	Nakhiloo	27.830	51.474				5	
Oman	Masirah	20.182	58.663				4	6
	Daymaniyat	23.858	58.109		2	5	3	5
Qatar	Fuwairit	26.031	51.375			3	8	9
	Ras Laffan	25.952	51.506			2	2	2
UAE	Ghantoot	24.920	54.910			1		2
	Sir Bu Nair	25.211	54.237			4	3	6
	Qarnayn	24.937	52.870	2			4	
	Zirqu	24.874	53.064					6

2.2 TRAVEL & LOGISTICS

Given turtles nest multiple times in a season on roughly two-week intervals, the project also aimed to collect data on where turtles were distributed and the duration of the internesting periods. The project deployed PTTs as early as possible in the nesting season at each location, based on previous published literature (Pilcher 1999, EAD 2007, SCENR 2006). The ensuing tracks were then visually analysed and all points prior to the departure from the nesting site in a purposeful manner towards the feeding grounds were categorised as internesting (the period post-deployment until departure from the nesting site). Each approximate two-week block during of internesting behaviour was considered a subsequent nesting event based on known internesting interval for Gulf hawksbills. This permitted a rough extrapolation of the average number of nests per turtle per season at each rookery.

The logistics of having a field team at each rookery as close to the start of the season as possible across four countries proved a formidable challenge. In April turtles started nesting in Iran and at the Daymaniyat islands in Oman. By May turtles had started nesting on the islands spread across the UAE and by mid-May to early-June nesting had commenced in Qatar and at Masirah. The temporal spread in commencement of nesting meant the project team moved quickly from one country to another, and often had to split up and be in two countries at once to encounter the earliest nesters. Timing for each field trip was carefully planned in consultation with local partners, who provided local logistical support and permits.

2.3 SATELLITE TRANSMITTER DEPLOYMENT

At night the project team patrolled the nesting beaches in search of nesting turtles. Preference was given to turtles which had already laid eggs, but given timing constraints, the need to deploy the transmitters early in the season, and travel logistics, the team often had to select turtles which had yet to lay eggs. Where multiple turtles were available, those to be tagged were selected at random.

Figure 5: Two of the collapsible metal restraint boxes used to temporarily hold the turtles.

2.3a Turtle Restraint

Following nesting, turtles were restrained in custom-designed stainless steel boxes (Figure 3). The boxes were designed as lightweight, stainless steel low-cost collapsible restraints to address the needs of a multi-country project that required frequent movement of gear and tagging supplies by commercial air travel. When the turtles were restrained, their curved carapace length (CCL) was measured over the curve of the carapace along the midline from the anterior point of the nuchal scute (the one behind the neck) to the posterior tip of the supracaudal scutes (the two tail scutes which form a small V notch at the rear of the carapace).

2.3b Transmitter Model

Turtles were tracked with Kiwisat 101 satellite transmitters called Platform Terminal Transponders (PTTs) made by Sirtrack Ltd., programmed for a duty cycle of 8 hours on / 16 hours off and synchronised to operate during daylight hours. The shorter operating time meant that the transmitter battery life was extended substantially, with little compromise on the volume of data received. In addition to the duty cycle programme, saltwater switches restricted transmission only to periods when the unit was at the surface to further extend battery life. The transmitters had stainless steel contacts at the front and at the rear of the units. When the turtle was submerged, a connection was made via the salt water across the terminals which turned the unit off. As the turtle surfaced, contact was broken and the transmitter – provided it was at the correct duty cycle – turned itself on and sent a signal to an orbiting satellite.

2.3c Satellite Transmitter Attachment Protocols

PTTs were attached using a modified version of the Balazs *et al.* (1996) fibreglass and resin attachment. The attachment zone was sanded with rough sand paper to make it abrasive, and then cleaned with alcohol and a cloth several times. A surgical-grade elastomer rubber-like compound was used as a base between the PTT and the turtle, as the PTT was flat and the turtle shell was rounded. The PTT was then affixed to the centre line of the carapace slightly overlapping the front-most scute. Three layers of glass cloth were then used to hold the PTT in place using fibreglass resin (Figure 6). All layers were allowed to dry until completely solid and smooth (often this required an overnight wait) and then temporary covers to the salt-water switches were removed. The final third fibreglass layer was modified slightly to consist of two long (~35 cm) thin (~3 cm) strips affixed diagonally across the PTT from front left to rear right, and front right to rear left. This maximised the number of scutes to which the PTT was attached.

Figure 6: PTT being affixed on top of the turtle carapace using fibreglass cloth and resin.

2.3d Turtle Release

Once the PTTs were securely affixed to the turtles, the turtles were tagged with either a titanium tag (Stockbrands Ltd, Australia; in Oman and Qatar) or Monel tag (National Band & Tag Co., USA; in Iran and UAE), and a single use 3 mm biopsy punch or sterile razor blade was used to take tissue sample for genetic analysis. Following this the metal boxes were removed and the turtles were allowed to crawl back down the beach to the sea with no interference.

2.3e Data Acquisition & Processing

Satellite signals were sourced from Argos with Kalman filtering (www.argos-system.com) and automatically downloaded by the Satellite Tracking and Analysis Tool (Coyne & Godley 2005). When the turtles surface, the transmitters send a signal to an orbiting satellite, which processes the data and relays the information to the project daily. These polar-orbiting satellites constantly circle the planet, and are not always 'visible' from a given spot on earth. If a turtle breathes at the surface for five to six seconds as the satellite passes overhead this results in a high quality signal. But if the satellite is emerging over the horizon when the turtle is on the surface, the angle of incidence is low and the accuracy of the data decreases. Similarly, if the turtle dives when a satellite comes overhead or surfaces as one is departing, the contact is insufficient for an accurate fix. Location quality fixes provided by the Argos service are classified as location fix qualities 4, 3, 2, 1, 0, A, B, and Z. These location quality differences are interpreted as follows: Class 3 location signals are the most accurate, whereby the location fix sits at the centre of a potential location circle less than 150 m in diameter, an area slightly bigger than three average football pitches. That is, the turtle could be anywhere inside that circle and the location marker is merely the mathematical centre – not necessarily the turtle's location. Class 2 location signals have an accuracy around 350 m (i.e. the turtle could be anywhere inside a circle of 350 m in diameter, or roughly a city block). Locations become less and less accurate along the scale goes, to about 1000 m for a Class 0 location. Class Z signals are ignored completely. However, when location fixes in a row depict a fairly straight line from one place to another, there is a good chance this is what the turtle was doing. So while mathematical accuracy is based on areas (of accuracy circles), the turtle's relative movements are those of the circles themselves (Figure 7).

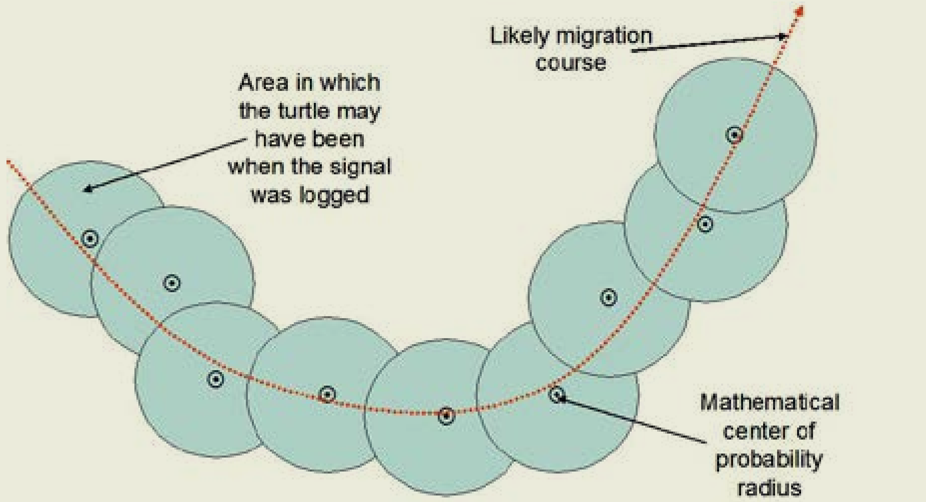


Figure 7: Graphical representation of location data and probable movement of a turtle.

2.4 DATA ANALYSIS & FILTERING

All location fix data was filtered to exclude locations over land, and then further filtered for location fix qualities 3, 2, 1, 0, A, and B, with a speed of ≤ 5 km/h between fixes (Hays *et al.* 2001). The A and B data were included due to the low latitude which limits the number of locations due to fewer Argos passes. To eliminate behavioural bias, only one fix per turtle per day was selected, choosing the highest quality fix. Where more than one signal of equal high quality was available, the point closest to midday was used (Zbinden *et al.* 2008). The data were further filtered for implausible data such as landlocked fixes, and positions thousands of kilometres from the previous fix.

In order to calculate total distance covered by each turtle during each activity, minimum distances were calculated assuming straight-line movements between the location fixes sets using the spherical law of cosines (Sinnott 1984) which accounts for the radius and the (near) spherical shape of the planet. That is, a straight line over the curve of the planet was calculated between each location fix. The minimum distance travelled was calculated assuming straight-line movements, and where tracks crossed landmasses the shortest route around the land mass was extrapolated using straight sectors. Average swim speeds per activity were determined by dividing total displacement by the time interval between start and end points for each activity. Data were tested for normalcy and analysed using Analyse-it 2.04. Circular data analysed using Oriana 4.02 following methods described by Zar (1984).

2.4a Life Stages (States)

Given the changes in turtle behaviour with time, location fixes were split into several categories depending on turtle activity, or States, as follows:

Internesting
The turtle tracks were visually analysed and all points prior to the departure point from the nesting site were categorised as internesting (the period post-deployment until departure from the nesting site). Within these data sets, each approximate two-week block during of internesting behaviour was considered a subsequent nesting event based on known internesting interval for Gulf hawksbills.

Migration
Location fixes subsequent to the commencement of foraging were categorised as migration fixes (direct purposeful travel from the nesting site with minimal deviation from a straight path).

Foraging
Foraging activity was inferred by a reduction in travel rates and a shift from purposeful migration direction and unidirectional orientation to short distance movements with random heading changes (Foley *et al.* 2013).

Summer Migration
Purposeful northeast movements into the middle of the Gulf from July-August, followed by returns in September-October were categorised as summer migration loops.

Thus the four States into which turtle behaviour was categorised were Internesting, Migrating, Foraging and Summer Loops.

2.4b GIS Mapping & Home Range Density Analysis

In its simplest form, “home range analysis” involves the delineation of the area in which an animal conducts its “normal” activities. Given the accuracy of location fixes whereby these might differ slightly from actual turtle location, and occasional short departures from normal foraging grounds, not every point that was visited, nor the entire area used by each turtle during the tracking period, was representative of the most important areas for each turtle. Instead, the project focussed on Home Ranges, which can be likened to “areas traversed by a turtle in its normal foraging, exploratory, and development activities”. Occasional forays outside of these areas, perhaps exploratory in nature or as flee reactions to predators, were not considered as part of the home ranges. The project also focussed on Core Areas for each turtle, defined as “those areas where turtles spent over half of their time”.

This study employed a Kernel Density Analysis process to determine Important Turtle Areas (ITAs). Kernel density analysis is a nonparametric statistical method for estimating probability densities from a set of points (in this case the location fixes for each turtle). In the context of home range analysis, these analyses describe the probability of finding an animal in any one place.

The method begins by centring a bivariate probability density function with unit volume (i.e., the “kernel”) over each recorded point. A regular grid is then superimposed on the data and a probability density estimate is calculated at each grid intersection by summing the overlapping volumes of the kernels. A bivariate kernel probability density is then calculated over the entire grid using the probability density estimates at each grid intersection. Finally, home range estimates are derived by drawing contour lines at different probability levels based on the summed volumes of the kernels at grid intersections. In this study home ranges were classified as areas where turtles were likely to spend 95% of their time, while core areas were calculated as those where turtles were likely to spend 50% of the time (Worton, 1989, Reese *et al.* 2012) for each turtle. When home ranges are combined with information about habitat type and condition, it is possible to estimate resources available to individual turtles in each population. These types of analysis result in a demarcation of important areas for turtles which can then be made available to conservation managers.

2.4c Secondary Data Analysis

Physical and biological environmental data used to describe the marine environment at the foraging grounds and during summer migration loops included sea surface temperature (SST), sea surface height (SSH) and geostrophic currents, along with surface Chlorophyll a density. These data were used to determine which oceanic parameters might be responsible for changes in behavioural state.

2.4d Sea Surface Temperature

Sea-surface temperature data comprised 9- km pixel (0.1 degree/pixel) resolution standard-mapped (Level-3) weekly composites between 2010 to mid-2013 via the NOAA OceanWatch - Central Pacific (OWCP) data portal (http://oceanwatch.pifsc.noaa.gov). This consecutive SST data was generated through the averaging of 3-hour global swath (Level-2) granules provided by NOAA NESDIS containing merged global polar orbiter satellite data (AVHRR-GAC and Metop-1/2). The data were then arranged in a time-series grid by 0.1 degree latitude × longitude intervals. The corresponding temperature data points were extracted from this grid relative to each turtles' position in space (spatially interpolated between grid points reflecting the resolution of environmental variables) and time, following which the relationships between these variables and the turtle location fixes and behavioural state were investigated, along with timing of behavioural shifts to explain the behavioural responses.

2.4e Localised Currents

The project also investigated the relationship of sea surface height (SSH) and the currents created by the pressure differentials between varying heights (where currents flow from high pressure areas to low pressure areas), along with Chlorophyll levels, which are a measure of ocean surface productivity, with turtle activity patterns to determine potential impacts on turtle behaviour. Weekly gridded 1/40 geospatial resolution sea-surface height data consisting of merged AVISO (http://www.aviso.oceanobs.com) multi-sensor sea-level anomaly data (Ssalto/Duacs gridded sea level data) were used to investigate relationships with sea surface height. These were combined with a sea-surface height climatology (Niiler *et al.* 2003) and derived geostrophic (current) velocities, along with weekly MODIS AQUA Ocean Colour with a geospatial spatial resolution of 0.010 latitude and longitude as a measure of Chlorophyll-a concentration

2.4f Habitat Bathymetry

Coarse bathymetry data sets were obtained from the U.S. Naval Oceanographic Office (NAVOCEANO). The Digital Bathymetric Data Base Variable resolution (DBDBV) is a digital bathymetric data base that provides ocean depths at various gridded resolutions. DBDBV was developed by NAVOCEANO to support the generation of bathymetric chart products, and to provide bathymetric data to be integrated with other geophysical and environmental parameters for ocean modelling. Grid resolutions used in this project were accurate to 2 minutes of latitude/longitude (1 minute of latitude = 1 nautical mile or 1.852 km). Fine scale bathymetry was obtained using a Garmin GPSMap 72 GPS unit pre-loaded with Garmin BlueChart g2 chart 2AW005R.

3.0 RESULTS & ANALYSIS

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This project would not have been possible without the collaboration between project partners; sharing knowledge, resources and expertise.

3.1 PROCESS RELIABILITY AND EFFECTIVENESS

Telemetry studies of sea turtles have increased by several orders of magnitude in the last two decades, and satellite tracking of sea turtles has progressed from a handful of turtles in 1982 to over 4,000 in 2006 (Godley *et al.* 2007). The number of tracked turtles has continued to increase since then, with decreasing costs and expansion of research programs across the planet. This is extremely relevant to conservation given the importance that this kind of spatial information provides to management authorities and conservation practitioners (Godley *et al.* 2007). This project made use of this latest technology to determine post nesting migrations of hawksbill turtles in the Arabian region, using the data to identify conservation bottlenecks and important turtle areas (ITAs) for conservation. Individual graphics for each turtle are presented in Annex A.

Key concerns with deployment of tracking packages on wildlife include retention rates, drag and interference with normal activities including mating, swimming and feeding, along with accuracy of location fix data. Unfortunately, given the one-way source of information provided by the PTTs, it is not possible to determine the basis for transmitter failure, although some of the diagnostic data sent by the transmitter assists in identifying (or dismissing) potential causes. For instance, turtle 105836 sent exclusively high-class signals after 28 April 2011, typically with over 10 messages per pass and long pass durations, and the signal strength was high. Coupled with PTT-relayed water temperatures of 43-46° these findings suggest that the turtle may have been captured lost early in the project. Turtle 105838 relayed adequate battery drain levels, normal temperatures (around 27°), and strong signal strength with numerous Class A & B locations - typical data for Arabian region sea turtles. However, signals were lost on 21 June 2011 and not reacquired. Similarly, data for 105840 was normal, and yet signals were lost after 03 June 2011. The tag was dry for some hours on 19 May (possibly emerging to lay eggs, as the gap between the dry event and her earlier spanned two weeks, that of a normal internesting period); battery current drain was normal, signal strength and temperature were normal. Several scenarios could account for the signal loss including vessel collision, capture in fisheries, predator attacks and sudden transmitter failure. However, insofar as the turtles were in apparent good health and active prior to signal loss, there are similarly no indications of any sudden ill-fate to the turtles.

Notwithstanding instances such as these, the average duration of the PTT signals in excess of manufacturer indications suggest the attachment techniques used in this project were sound and reliable. Similarly, the renesting events recorded by the project (and witnessed several times by rangers at several locations) suggest the transmitters did not interfere with nesting activities following deployment. The long periods recorded for practically all turtles at their foraging grounds, including temporary emigration due to summer warming events and returns to the foraging grounds, further support this notion.

Variations in transmitter longevity are more easily explained through two key variables: (a) Limited and varying energy supplies in the batteries; and (b) varying turtle behaviour and time spent at the surface. Not all batteries perform identically, and not all turtles behave the same way, and therein lies the variability. While technology improves daily and the unit manufacturers include circuitry to minimise battery drain, variability in battery manufacture and performance results in some batteries depleting faster than others. At the same time, not all turtles behave the same way, particularly as behaviour relates to spending time on the surface. The transmitters contain a salt water switch which allows the units to transmit only when the turtle is at the surface, thus if one turtle spends more time at the surface than another, the PTT will transmit for longer and deplete the battery faster.

3.2 TRACKING DATA LONGEVITY

PTT signal life recoded by this project ranged from 11 to 1125 days with an average of 320.4 days (SD=200.26 days). Of the 90 units tracked by this study, five were still active in February 2014, some 12 months after the end of the main tracking period. Only 16 units (~20%) transmitted for less than 50 days, while 20 units (~30%) transmitted for longer than 500 days. A and B quality location fixes accounted for 87.8% of all signals received. From project inception up to the cutoff date in August 2013 (for inclusion of data into the final analysis), the project was able to reliably use 20,485 data points filtered from a total of 92,789 location fixes received (22%).

3.3 TURTLE MORPHOMETRICS

There was a significant difference ($t=11.82$, $p<0.0001$) in curved carapace length between turtles in the restricted waters of the Gulf and those from Oman, which fronts the Indian Ocean. Turtles in the Gulf averaged 70.3 cm in curved carapace length (SD=3.37, range 65.0-78.5 cm), and were among the smallest on average across global adult size ranges, while turtles from Oman were over ten cm longer, averaging 81.4 cm in CCL (SD=3.36, range 75.0-89.5 cm). The smaller sizes of turtles in the Gulf are consistent with earlier findings and likely linked to extreme temperature fluctuations and food availability (Pilcher 1999).

3.4 RE-NESTING INTERVALS & OCCURRENCE

Sea turtles typically deposit multiple clutches per season (Van Buskirk & Crowder 1994). These may be spread over long drawn-out periods or compressed into short seasons when weather conditions are optimal (Miller 1997). In the Arabian region hawksbill turtles deposit multiple clutches and nest during short summer season, typically between April/May and July. However, given the short nature of many monitoring programmes, it is unknown what the total reproductive potential of the species comprises in the Arabian region.

Only saturation survey projects are able to determine the total number of nests per female turtle, when tagged individuals are recaptured at subsequent nesting events. To overcome the lack of saturation monitoring programmes, the project calculated the number of two-week intervals after deployment of the PTTs and prior to the commencement of migrations to determine a possible range of nesting frequencies. While not a precise, this parameter does provide an indication of subsequent nesting activity and reproductive capacity for hawksbill turtles in the Arabian region, which to date has been little studied.

Given the physical differences between turtles in the Gulf and those from Oman, data from each location were considered separately. There was no significant difference in nesting activity by turtles from the Daymaniyat islands or Masirah (ANOVA F=0.77, p=0.386), and these data were then grouped for further analysis to provide a composite figure for Oman. The average subsequent nesting period (post-deployment and prior to migration) for turtles in the Gulf was 20.1 days (SD=14.84, range 0-76 days) representing an average of 1.4 nesting cycles with a possible range 0 to 5 nesting events.

The average nesting period for turtles from Oman 11.1 days (SD=14.48, range 0-45 days) representing an average of 0.9 nesting cycles with a possible range 0 to 3 nesting events. While the nesting periods for turtles in Oman appeared to be slightly lower than those for the Gulf, these were not statistical different (Mann Whitney U=547.0, p=0.0105). Six turtles from the Gulf (~8%) had no subsequent nesting period at all and departed the nesting area immediately after tag deployment. In contrast ten turtles from Oman (~29%) departed immediately after PTT deployment.

Overall these results suggest Arabian region hawksbills have the capacity to nest up to 6 times in a season (the nesting event witnessed by the team and 5 additional ones), but that on average nesting is likely to be closer to 3 events per season, with lower nesting activity by a higher proportion of turtles in Oman than in the Gulf.

Data on total reproductive output at a regional level can provide an understanding of population robustness and would allow managers and conservationists to track population performance over time. These efforts to determine total potential reproductive output per turtle were based on deployment of transmitters as early as possible in the season, and subsequent estimation of time spent at the nesting grounds prior to purposeful migration to feeding grounds.

Turtles from Oman deposited fewer clutches on average than those in the Gulf, and based on detention periods in internesting grounds following PTT deployment, we estimated turtles could potentially deposit up to five additional clutches (for a total of six), but that the norm was for them to deposit an average of three clutches per season. These findings are consistent with earlier saturation tagging in Saudi Arabia (Pilcher 1999, Al-Merghani *et al.* 2000) and the short seasons experienced by most nesting sites in the region. The results may be used as a guide until further evidence-based findings are forthcoming.

3.5 REMIGRATION INTERVALS & OCCURRENCE

At the conclusion of each nesting season, turtles do not (typically) nest in successive years. Intervals may span from two to >10 years, generally dependent on food availability (Miller 1997). Tracking periods for turtles during this study averaged ten months; three turtles were tracked for periods lasting two years, and only one turtle was tracked for three years. No remigrations were recorded from any of the turtles tracked during this study, suggesting (albeit with a small sample size given the average duration of transmissions) that remigration intervals are typically greater than three years.

3.6 TEMPERATURE-INDUCED SHORT-TERM MIGRATIONS

An interesting finding by this project was in the form of a temporary emigration by turtles from shallow warm waters to deeper and cooler waters during summer months. This discovery of short-term summer migration loops amongst Arabian turtles was unique and novel. Sea surface temperatures during the summer months averaged 33.5°C and peaked at 34.9°C (Figure 6), far higher than places such as the Caribbean and major ocean basins where temperatures rarely exceed 30°C. During these elongated periods of elevated temperatures (June-August) the turtles temporarily emigrated to deeper and cooler waters at northern latitudes, generally returning after 2-3 months (September-October) back to original feeding grounds.

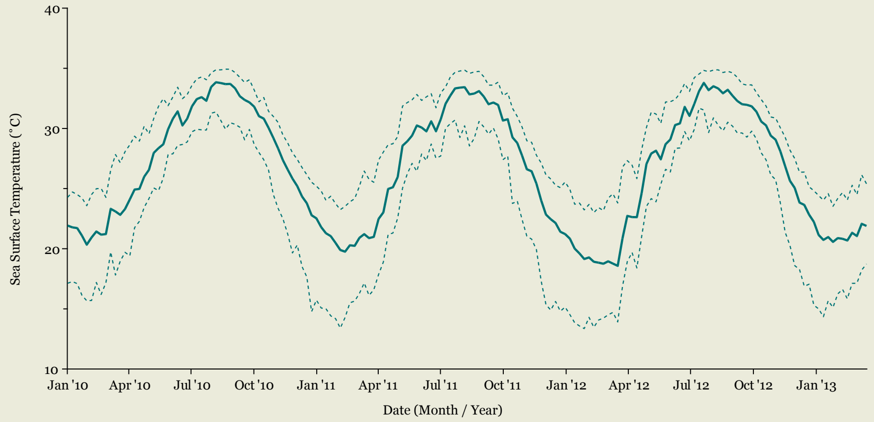

Figure 8: Average Gulf-wide weekly temperatures across all 9-km pixel blocks (solid black), with 90%ile (grey) and maximum and minimum ranges (dotted lines) between 2010 and mid-2013. Straight dotted line represents 30°C. Data courtesy of NOAA NESDIS.

Summer migration loops were unique only to turtles residing in the Gulf, thus data for the 31 turtles were tracked outside of the Gulf where this behavioural phenomenon was not noted were not included in these analyses. Of the 66 hawksbill turtles that were tracked within the Gulf, only 55 turtles (83.3%) which had settled in foraging grounds prior to commencing a summer migration loop were selected to ensure consistency in interpretation of results. Of these, 11 turtles were tracked over second summer migration loops the following year, for a total of 66 summer loop events. At the end of the summer loops, 46 (70%) of the turtles returned to foraging grounds for extended periods, and these foraging periods were also included in the analysis. In all, we compared event dates, swim speeds, latitude, latitude shifts, initial bearings against water temperatures, geostrophic currents and sea surface height, along with Chlorophyll-a, amongst 66 summer migration loops and 112 foraging periods.

The term summer migration loop was derived from the overall timing of the behavioural shift and the return to the same or a nearby foraging ground (Figure 7). Return paths did not necessarily retrace the outbound path during the summer migrations, and were invariably more circuitous than direct to-from journeys. The earliest summer migration started on June 11 and the latest started on 18 August. The earliest migration loop ended on 28 June while the latest ended on 16 December. Even though there were some late starters, over 75% of migration loops commenced prior to the end of July and similarly, while there were some early returns, over 83% of all migrations ended from September onwards. Overall, migration loops typically started in June or July and were completed by September or October. Behaviour shifts were generally synchronous irrespective of country (and rookery) of origin.

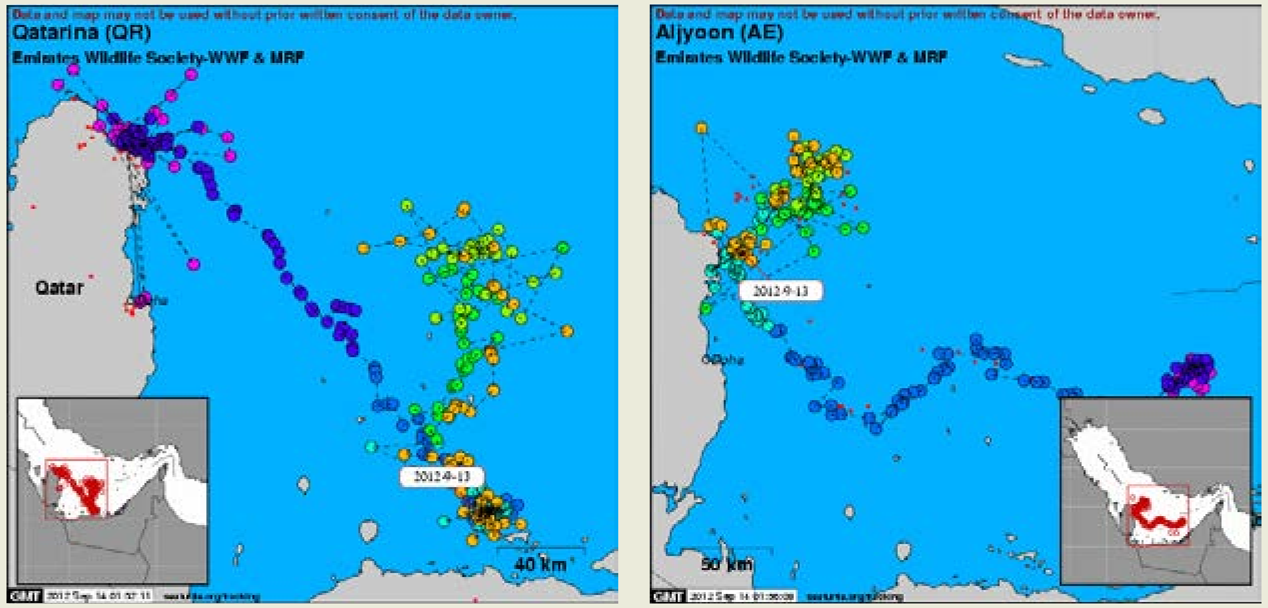

Figure 9: Two typical migration loop tracks, one from Qatar and one from the UAE, with lighter coloured location fixes depicting the movements away from and return to the original foraging grounds. Outbound paths rarely were retraced during the return journey, with turtles undertaking a more circuitous route.

Summer migration loops were marked by an end in multi-directional movements and slow swim speeds and the onset of more purposeful, unidirectional headings and increased swim speeds. There was a significantly higher swim speed during the summer loop state than in foraging state, with foraging animals averaging 4.6 km/day (SD=2.63, range 1.1-16.4 km/day) and summer loopers doubling this to an average of 10.9 km/day (SD=3.28, range 5.5-19.7). Overall loop distances covered by turtles during the summer migrations averaged 647 km (SD=336.6, range 145-1594 km). The increased swim speed and distance between location fixes was typical of all summer migration loops indicating a clear shift in behavioural state.

Turtles undertaking summer migration loops generally moved in a north-easterly direction toward deeper sections of the Gulf, returning in a south-westerly direction to the shallower foraging grounds. There was a significant difference in direction of outward and return travel during the loops, with outward migration bearings averaging 30.60 (SD=38.310) and return bearings averaging 203.40 (SD=35.820) with turtles residing in the south-western extent of the Gulf generally heading out in a NE direction toward deeper and cooler waters.

There was a small but significant difference between sea surface height (SSH) at the end of the foraging period (just prior to commencing the summer migration) and at the height of the summer migration loop, which might have influenced turtle behaviour – although it is uncertain how this would be manifested within such a relatively small body of water. However, there were no significant differences between SSH when all foraging values were considered (x=8.6, SD=6.30, range -9.2-27.9) against all summer loop SSH values (x=9.0, SD=5.63, range -5.9-27.1), suggesting SSH was not a key driver behind selection of alternate summer habitats. Geostrophic currents, which are derived from SSH data, were similarly inconclusive. Similarly, there were no significant differences in Chlorophyll-a concentration between foraging grounds and summer migration temporary habitats, and the data were not significantly correlated (r=0.11, p=0.446). Chlorophyll-a concentrations at foraging grounds averaged 1.38 mg/m^3 (SD=0.984, range 0.41-7.91) and were only slightly higher than those found at the summer migration habitats which averaged 1.30 mg/m^3 (SD=0.759, range 0.25-3.19).

However, while there were no apparent relationships between location in time and space and SSH, geostrophic currents and Chlorophyll-a, we did find that the summer migrations were all linked to significant differences in water temperature, strongly suggesting that the temporary emigration was a behavioural response to elevated temperatures. We determined water temperatures at the locations just prior to the point of departure and compared these to water temperatures at the middle of the loops and at the extreme latitudes reached by each turtle during the summer migration loops. There was a significant increase of roughly 2°C between the sea surface temperatures at the end of foraging / start of the migration (x=31.9°C, SD=2.08, range 20.32-34.72°C) and at the middle of the summer loops (x=29.7°C, SD=5.01, range 17.31-34.67°C), and waters had cooled at the foraging grounds by the time the turtles returned from the summer loops by roughly 1.5°C (x=30.5°C, SD=4.50, range 18.91-34.05°C). Overall, the turtles departed from significantly warmer waters and occupied waters roughly 2°C cooler at the apex of the migration loops, not returning until waters had cooled substantially in the lower south-western reaches of the Gulf whereby they resumed normal foraging behavioural states.

3.7 MIGRATIONS

Location fixes from the point of departure from the internesting habitat until the commencement of foraging were categorised as migration fixes (direct purposeful travel from the nesting site with minimal deviation from a straight path). Turtles were grouped into three relatively distinct groups based on migration activity and deployment area: those deployed in the Gulf proper, those deployed on the Daymaniyat islands off Oman, and those deployed off Masirah Island in Oman, the latter two being >400 km apart and separated geographically by Ras Al Hadd, the easternmost headland on the Arabian peninsula.

- Turtles in the Gulf proper generally moved in a S or SW direction towards the SW corner of the Gulf shared by the United Arab Emirates, Saudi Arabia and Qatar, although a small proportion of turtles travelled into the Gulf of Salwa (between Qatar and Saudi Arabia) and northwards towards Bahrain, Saudi Arabia and Kuwait (Figure 10, Figure 11 & Figure 12).
- Turtles from the Daymaniyat islands tended to head SE along the coast of Oman, rounding Ras Al Hadd and heading SW towards foraging sites off the mainland coast near Masirah and further towards the Yemen coastline (Figure 13).
- Turtles from Masirah, interestingly, rarely travelled further than 50-80 km to coastal foraging sites off the Oman mainland coast, with the exception of one turtle which travelled 350 km to the SW (tag ID 115254; Figure 13). Given the disparity in distances covered by Omani turtles, the two latter figures are shown at a different scale than those from the Gulf.

Initial migrations from the internesting habitats to first settlement at foraging grounds in the Gulf proper were short in duration, and completed within an average of just 10.3 days (SD=7.73; range=1 to 32.9 days; n=61); The migrations covered short distances, averaging only 189.4 km (SD=138.53; range 12.8 to 659.6 km - the longest being one single track by a single turtle swimming from Qatar all the way north to Kuwait; Figure 11). Within the Gulf, the migrations by turtles from Iran generally were the longest (average=361.8 km; SD=136.66, range=200.9

to 536.1 km; n=10) and took an average approximately 20 days to complete.

In Oman, migrations from the Daymaniyat islands were the longest, averaging 672.6 km (SD=249.1, range=66.4 to 1092.1 km) and taking an average of 28.6 days to complete (SD=13.38, range= 3.2 to 55.1 days), with all but two turtles reaching or passing Masirah island on Oman's south coast. One of the two remaining turtles (tag ID 53003) migrated into the Gulf via the Straits of Hormuz in the first documented instance of a hawksbill migration in or out of the Gulf. The second was believed to be taken on board a vessel as the last readings were all dry prior to cessation of signals, and given the departure away from the Arabian peninsula in contravention of typical migration routes (tag ID 105836). Migrations by turtles from the Daymaniyat islands were statistically greater than those from turtles within the Gulf.

In contrast, migrations by turtles deployed on Masirah islands were the shortest of all, averaging only 80.5 km (SD=93.9; range= 6.6 to 324.9 km; n=10) and lasting only an average of 3.95 days (SD=3.49, range = 1=12 days, n=9). These migrations

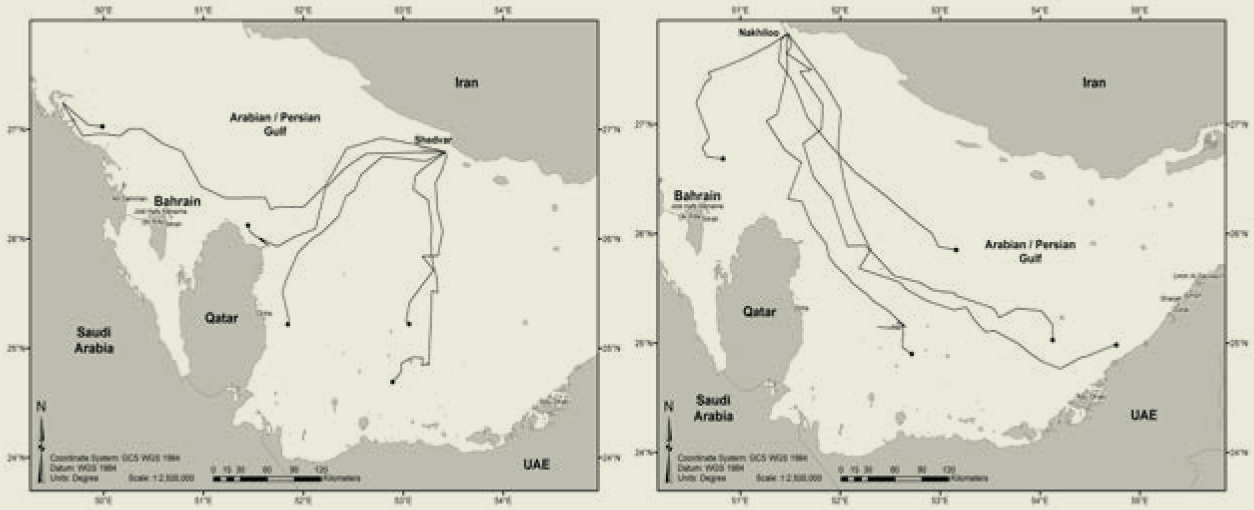

Figure 10: Trajectories of post nesting migrations until commencement of foraging activities (black circles) as turtles departed from Shedvar (left) and Nakhiloo (right) in Iran. Foraging and subsequent movements removed to simplify viewing.

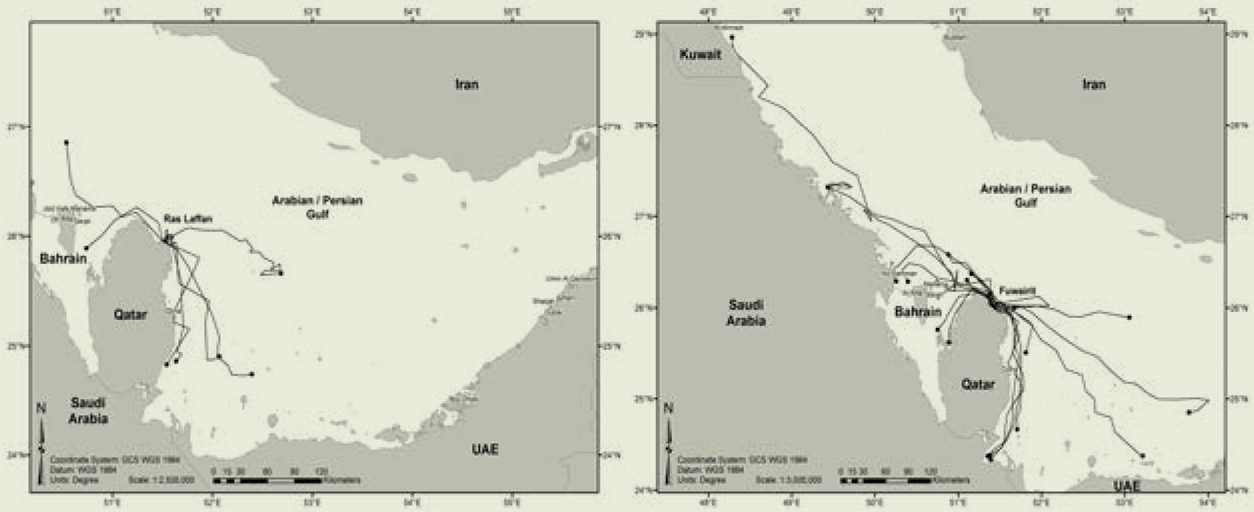

Figure 11: Trajectories of post nesting migrations until commencement of foraging activities (black circles) as turtles departed from Ras Laffan (left) and Fuwairit (right) in Qatar. Foraging and subsequent movements removed to simplify viewing.

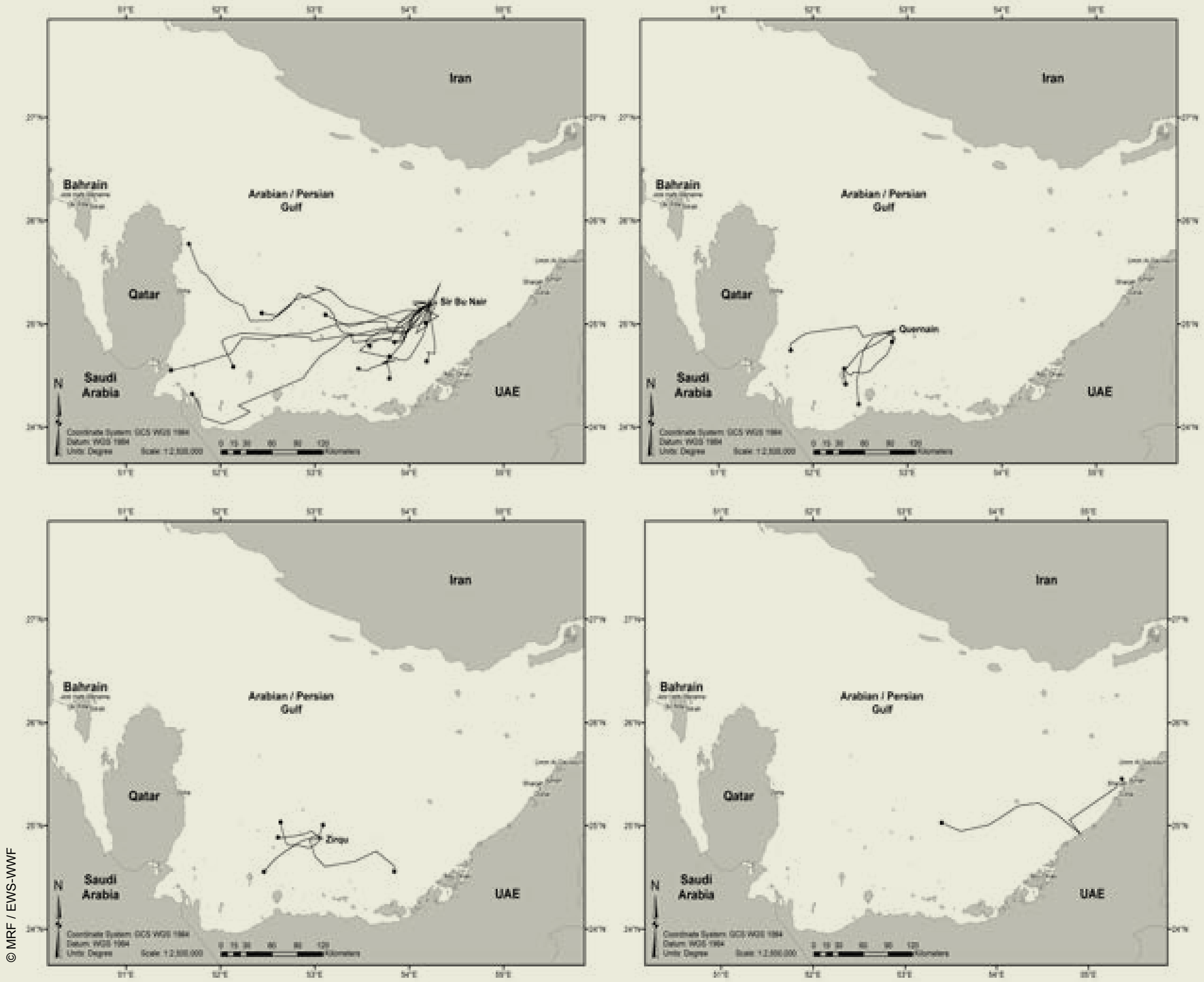

Figure 12: Trajectories of post nesting migrations until commencement of foraging activities (black circles) as turtles departed from Sir Bu Nair (top, left); Quernain (top, right); Zirqu (bottom, left); and Ghantoot (bottom, right) in the UAE. Foraging and subsequent movements removed to simplify viewing.

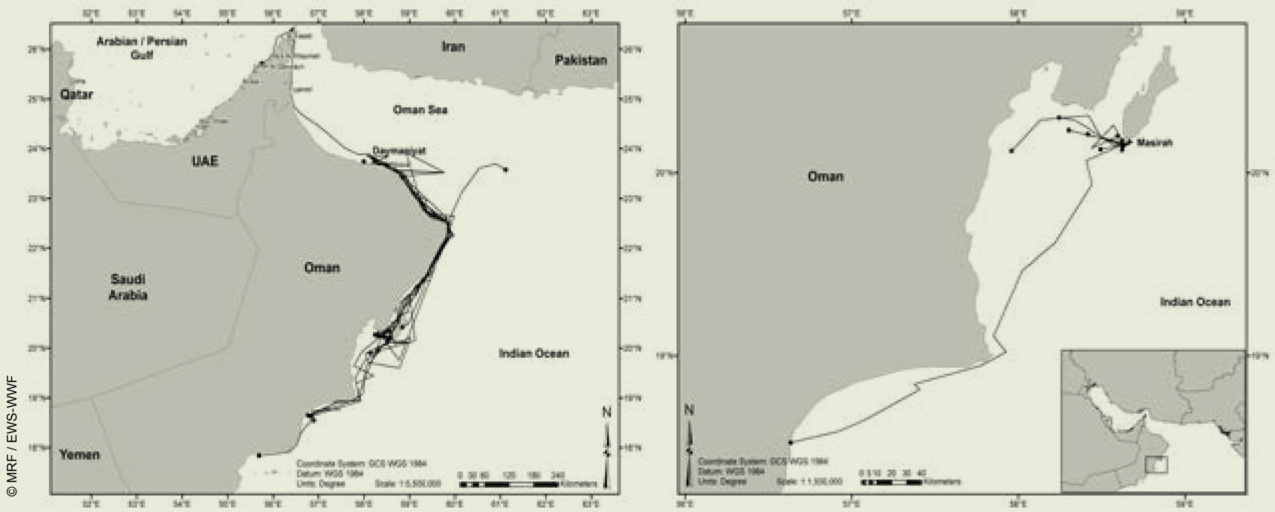

Figure 13: Trajectories of post nesting migrations until commencement of foraging activities (black circles) as turtles departed from the Daymaniyat islands (left) and Masirah (right), Oman. Foraging and subsequent movements removed to simplify viewing.

were statistically shorter than migrations in the Gulf or the Daymaniyat islands.

A subset of 17 individual turtles (19%) which had spent substantial periods at a foraging ground undertook subsequent migrations to secondary or tertiary foraging grounds. These migrations differed from summer migration loops in timing, distance covered, and orientation. Among these turtles, secondary migration distances were somewhat shorter, averaging 231.1 km (SD=218.68, range= 13=766) but not significantly different when compared to primary migrations averaging 262.3 km (SD=278.03; range 18 to 1165 km; n=31). Only seven (22.5%) of these events occurred inside the Gulf suggesting a greater need by turtles along the mainland Oman coast to expand their foraging ranges.

Swim speeds during migrations by turtles in the Gulf averaged 18.2 km/day (SD=7.73; range 0.7-34.7 km/day; n=71). Turtles from the Daymaniyat islands averaged 21.4 km/day during the migrations to foraging grounds (SD=6.32; range 7.7-33.3 km/day; n=27) while turtles Masirah averaged 18.8 km/day (SD=12.0; range 2.7-51.4 km/day; n=21). Swim speeds by turtles undertaking migrations were not significantly different between the Gulf, Masirah or the Daymaniyat, with an overall swim speed during migrations of 19.02 km/day.

3.8 FORAGING HABITATS

3.8a Distribution

One of the key objectives of this study was to identify the location of foraging grounds for Arabian hawksbill turtles. The project determined that gulf hawksbill turtles are very specific about staying at their foraging grounds once they reach them, and their movements, once there, are very limited. Their foraging grounds were identified by a sudden reduction in travel rates and a shift from purposeful, rapid and unidirectional orientation to short distance movements with random heading changes. In addition to their initial foraging settlement areas, a subset of turtles undertook secondary and tertiary migrations to new foraging grounds, possibly in search of improved forage conditions. After the summer migrations many Gulf turtles settled at different foraging grounds so that a total of 164 foraging periods at 113 unique foraging sites were recorded, with widely varying durations (x=123.2 days, SD=132.66, range 11.02-1053.04 days).

Characteristic of the foraging periods was an overall slower swim speed (x=4.5 km/day, SD=2.41, range 1.1-16.4; n=174), some five times slower than that during migrations (19.02 km/day) and half that of swims during the summer loops (10.9 km/day).

We computed the size of the turtles' home ranges (95% density of foraging location fixes) and core areas (50% of foraging location fixes) by separate foraging events to describe the spatial extent of individual foraging grounds. Home ranges varied in size but overall were relatively small, averaging only 48.7 km^2 (SD=26.01, range=5.9 to 166.1 km^2). This is equivalent to the area of a circle of some 4 km in radius. The wide variation in sizes was not evenly distributed, with the majority of home ranges between 40 and 60 km^2 (Figure 14). In contrast core areas were extremely precise, focussed on individual shallow patches and averaging only 3.3 km^2 (SD=0.72, range=0.4 to 7.5 km^2). Here again core areas were not evenly distributed, with the majority of core areas measuring only 3 to 5 km^2 (Figure 14).

Home ranges and core areas were positively correlated (r^2=0.72), although core areas tended to remain small even when home ranges in some instances increased in size (Figure 15). Gulf home ranges averaged 52.4 km^2 and were significantly larger than home ranges for turtles outside of the Gulf (x=39.7 km^2), and similarly so were core areas (Gulf x=6.0 km^2; Oman x=3.2 km^2), suggestive of higher quality foraging grounds fronting the Indian Ocean than in the climate-challenged Gulf.

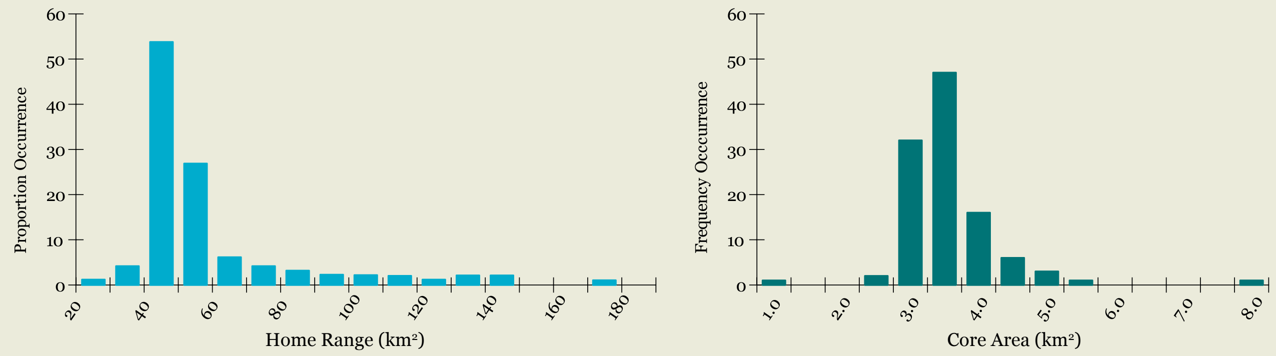

Figure 14: Size distribution of home ranges (left) and core areas (right) for hawksbill turtles in the Arabian region

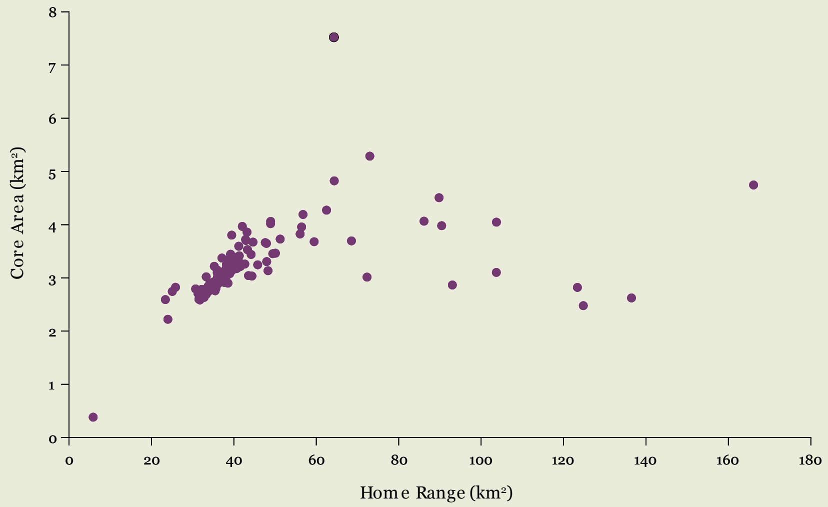

Figure 15: Relationship between home ranges and core areas for hawksbill turtles in the Arabian region.

In the Gulf, turtles occupied discreet and isolated foraging grounds, often returning to the same areas following two-to-three month summer migrations but frequently also moving to new areas. Given the propensity for turtles to migrate in a south and southwest direction, the majority of foraging grounds were located in waters off Abu Dhabi and southern Qatar, with only a handful of foraging grounds further north along the Bahrain, Saudi and Kuwait coasts (Figure 16). Of note is that no turtles headed east towards Iran and the eastern reaches of the UAE, which receive the cleaner waters entering the Gulf from the Gulf of Oman. In Oman, turtles from both the Daymaniyat islands and Masirah island migrated primarily to waters off Shannah, on the mainland adjacent to Masirah, with an additional few heading to Quwayrah, approximately 250-300 km further SW off the Omani coast and one travelling even further south (Figure 17).

By far the primary activity for turtles in the Gulf was foraging (or at least time spent resident in foraging areas) with turtles occupying an average of 68.0% of their time in foraging grounds, compared to 6.6% of their time in the internesting grounds, and only 4.9% of their time migrating between the two (Table II). Of note, Gulf turtles spent an average of 20.4% of their time on the summer migration loops, which is a substantial proportion of their time each year spent away from the traditional foraging grounds. In contrast Omani turtles in the Indian Ocean did not undergo summer migrations, but nested fewer times, spending only 4.4% of their time at nesting grounds, and undertaking longer migrations occupying 12.7% of their time. The largest proportion of time (82.9%) was spent at foraging grounds, many of these <50 km from the Masirah nesting site (Detailed activity data for each turtle is presented in Annex B).

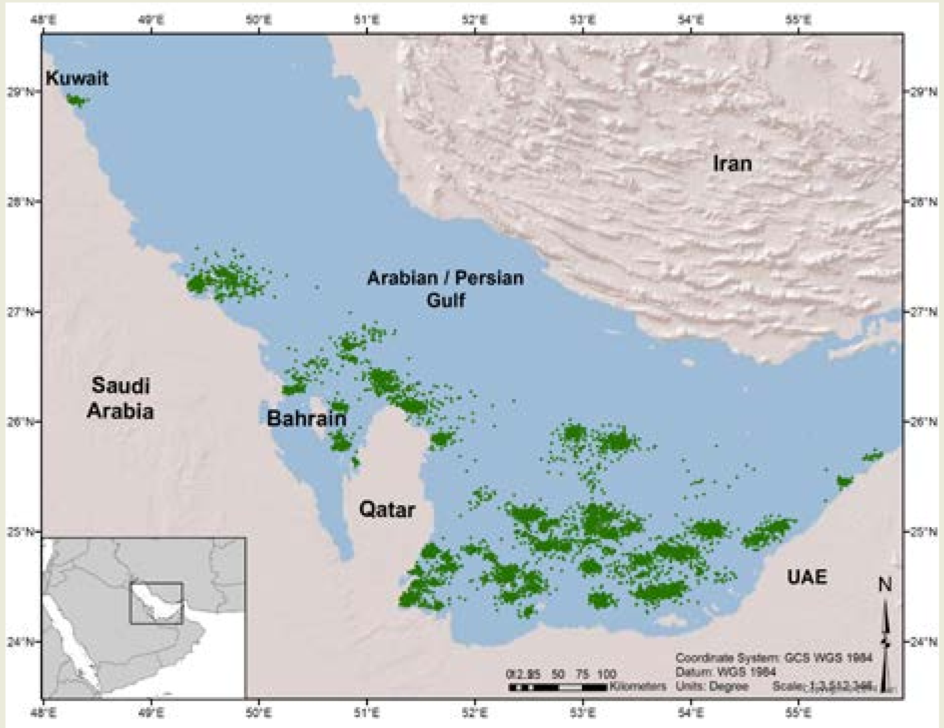

Figure 16: Locations of individual hawksbill turtle foraging grounds in the Gulf depicting a concentration of foraging grounds in waters off Abu Dhabi and southern Qatar, with only a few foraging sites north off Kuwait, Saudi Arabia and Bahrain.

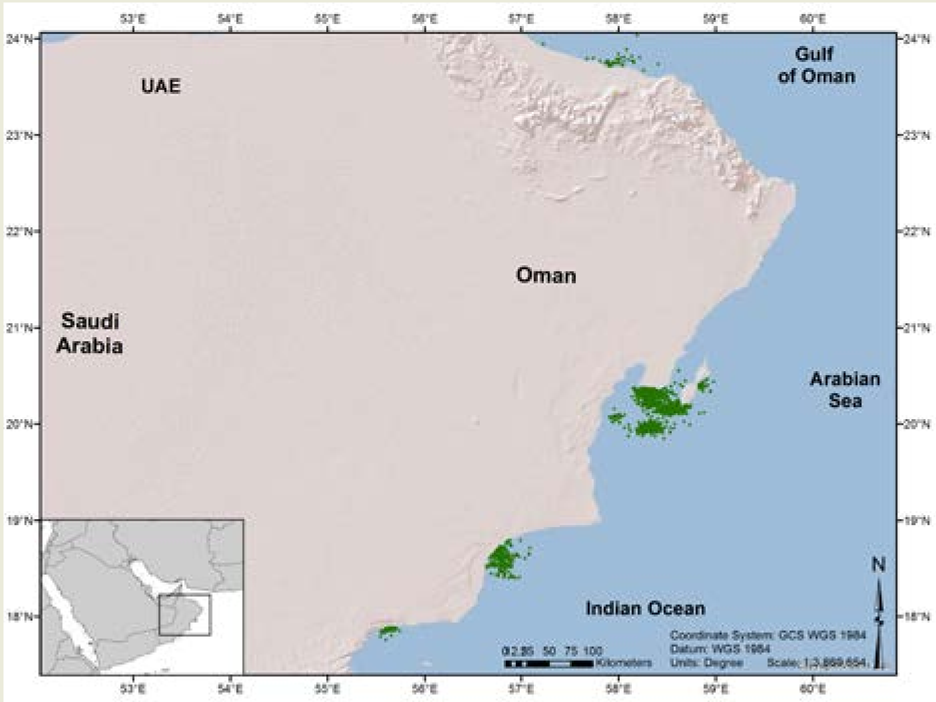

Figure 17: Locations of individual hawksbill turtle foraging grounds off the coast of Oman depicting the concentration of foraging grounds west and south of Masirah.

3.8b General Descriptions

Ground-truthing of five of these sites in the Gulf in 2013 confirmed extensive sparse seabed areas surrounding single shallow 'hard substrate mounts' dotted with individual coral colonies and small isolated sponge structures. This is consistent with findings of home range and core areas, whereby core areas were represented by single or multiple small 'seamounts' or shallow areas where sparse corals and reef-associated invertebrates settle.

A notable point from the results was that the ground-truthed foraging sites were all different to one extent or another. Some had hard substrates, others had mostly coarse sand substrates. Others had a variety of small sponge species, while others were limited to one or two colonies. Some were recovering reefs (Bu Tinah) while not all the patch reefs (e.g. Sir Bu Nair) were recovering reefs but rather healthy coral outposts. These coral patches were into themselves different, not being typical 'patch reefs' with major seabed coverage, but rather sand patches with numerous small 'windblown' domed coral colonies (Figure 18).

The foraging sites were generally characterised by a rubble substrate with small (5-20 cm diameter) individual colonies, rarely forming clumps or outcrops,

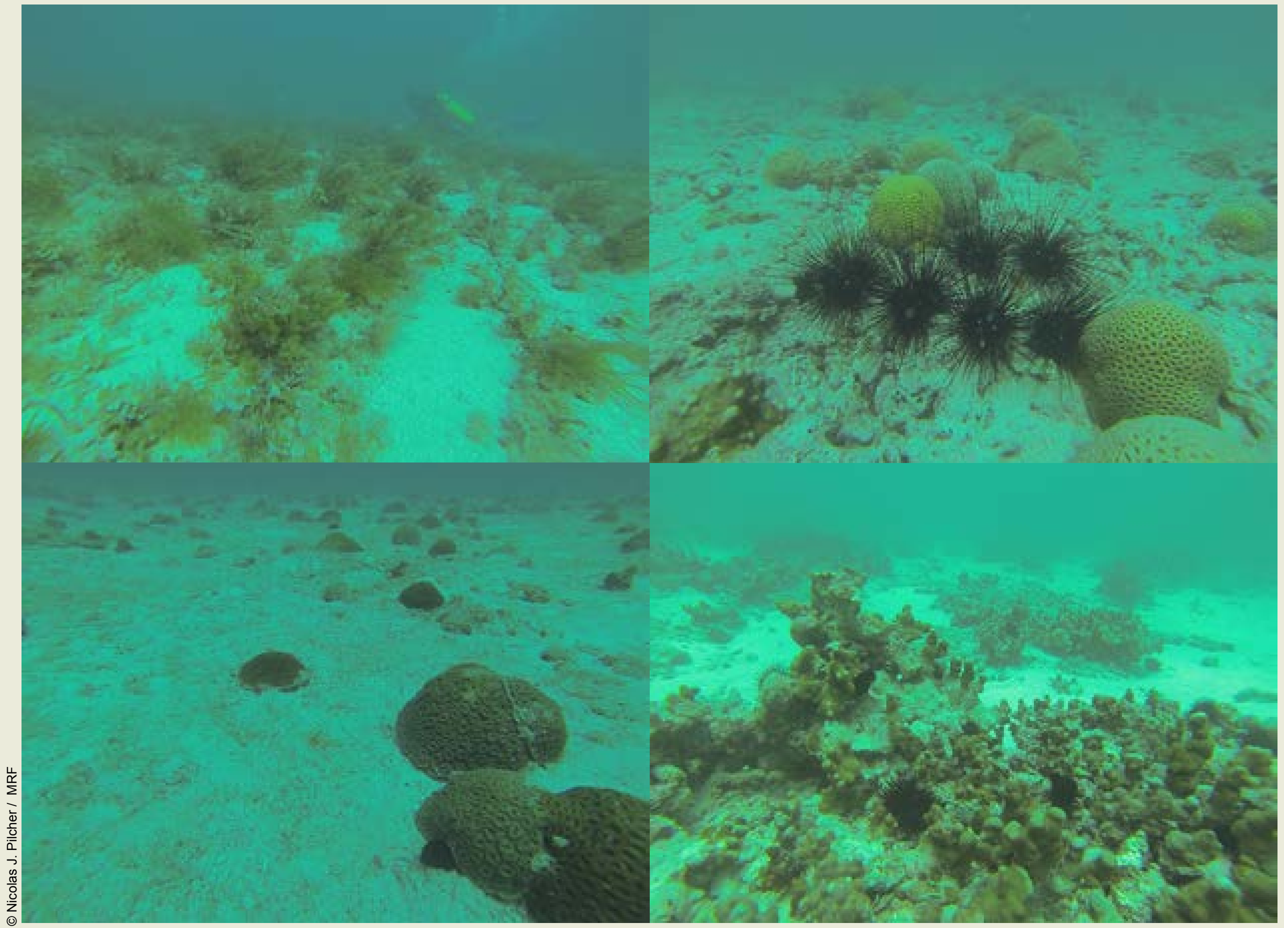

Figure 18: Generic photographs from ground-truthing surveys: Gracilaria filamentous algae (top left); Diadema spiny urchins on barren reef (top right); 'windswept' low domes coral colonies (bottom left) and high relief fossil coral areas with pioneer Porites coral.

suggesting high current areas over the top of the shallow reef patch – likely during tide shifts and shamal wind periods. The rubble patches were mostly devoid of growth possibly due to the grazing nature of the high numbers of short-spine *Diadema* sp. herbivorous urchins. Amongst the slightly more dense assemblages of coral colonies were long-spine urchins, occasional sponge colonies, and small numbers of fish – few of these commercial. Reef fish were dominated by the Queen Angelfish (*Pomacanthus maculosus*), along with double-bar seabream (*Acanthopagrus bifasciatus*) (common), and Striated Surgeonfish (*Ctenochaetus striatus*). Commercial fish included Snappers (*Lutjanus* spp.), Emperors (*Lethrinus* spp.) and occasional trevally (*Carangoides fulvoguttatus*).

The primary coral species identified at foraging sites were *Acropora* sp., *Astreopora* sp., *Favia* sp. and *Platygyra* sp. Hard coral cover usually only accounted for <25% of the substrate, and sponges were rare except in small colonies 5-10 cm across, at low densities (~5-10 colonies/10 m^2). Sand, rock and rubble accounted for the majority of the substrate, depicting a sparsely covered substrate with small individual coral colonies. Sites with substantial ancient reef cover (e.g. Bu Tinah and Abu Al Abyad) were characterised by recovering reef substrate following bleaching events in the more than a decade earlier. These sites were characterised by substantial reef relief (over 1 m in height) with interspersed sand patches, but where most of the coral structures were covered by macroalgae and coralline algae – with a distinct shortage of live coral colonies. Similarly, there were few sponge colonies to provide forage preferred material to hawksbill turtles. At some of the more degraded sites there were dense patches of hydroids (*Algaophenia cupresina*), along with the brown algae (*Caulerpa* sp.), Ascidians (*Ascidea* sp.), and filamentous red algae (*Gracilaria* sp.).

Taking into account the traditional understanding that hawksbill turtles are primarily spongivores, the sites came up short in terms of being dense reef areas with a suite of sponge species for hawksbills to choose from. The areas were always shallow (<10 m) and did contain some sponge colonies, but these were invariably small (with the exception of the larger colonies recorded at Bu Tinah which are not known as turtle forage material). It is possible the hawksbills are moving to other patch reefs in the vicinity, but bathymetric charts indicated that these were not common within the dense aggregation of forage point data. Similarly, it is possible the turtles are feeding on more than just sponges, but additional studies are needed to determine feeding habits of Gulf hawksbills.

4.0 DISCUSSION

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For the first time, using underwater cameras the project was able to identify the type of habitat used for feeding by hawksbill turtles in Abu Dhabi waters.

4.1 SUGGESTED CONSERVATION NEEDS

Sea turtles are vulnerable to anthropogenic impacts across their range. They are vulnerable when they emerge to nest. They are vulnerable to fishing nets drifting aimlessly at sea. They can be entangled in fishing lines, and entrapped in cooling water intakes. They are hunted as food, and to supply a curio trade. Being long-lived (Heppell *et al.* 2003) and of late maturation (Miller 1997) they face a multitude of threats over long periods of time. Of the seven extant species, two are listed as Critically Endangered globally (the hawksbill and the kemp's ridley – only found in the Gulf of Mexico and the western Atlantic), two as Endangered (the green and the loggerhead), two as Vulnerable (the olive ridley and the leatherback) and one as Data Deficient (the flatback – but only because sufficient data has not yet been assimilated to determine a status) on the IUCN Red List™. All turtles are listed on Appendix one of the Convention on the Trade in Endangered Species (CITES) which stipulates that all forms of trade are illegal and shipment of samples requires import and export permits.

And yet turtle populations generally continue to decline, and the key drivers behind the decline are a lack of attention to the key biological requirements of sea turtles: They need beaches on which to nest – and these disappear at alarming rates. They need to breathe – but all too often are caught in illegal nets and drowned. They take decades to mature – but conservation projects and funding are usually measured only in years. To save sea turtles it is necessary to 1) understand their biological needs; 2) determine key threats; 3) design measures to mitigate those threats; 4) assign turtles a suitable level of value at a societal level (both public and private) to garner support for conservation measures, and; 5) implement the conservation initiatives over a suitable time frame to have an impact.

In an effort to address these conservation needs, understanding the location of critical turtle habitats and the times turtles spend at these is essential for the design of effective and efficient conservation programmes. The results from this project provide the first evidence of migration pathways and a critical bottleneck at Ras Al Hadd, the easternmost point of the Arabian peninsula; locations of foraging grounds and clustering of these in the SW Gulf and close to Masirah island in Oman; temporary summer emigration thermoregulatory responses among Gulf turtles, and proportion of time spend at various reproductive biology life stages for critically endangered hawksbill turtles. These data can now inform management agencies and conservation practices in a region home to one of the most climate-challenged marine habitats on the planet, subject also to immense urban expansion, shipping and petrochemical industry pressures, and which supports large nesting and foraging populations or endangered sea turtles. Armed with this information, management agencies will be better able to target effective and efficient conservation action. The individual findings from this project are addressed in the following sections.

4.2 INTERNESTING ACTIVITY

Sea turtles typically deposit multiple clutches per season (Van Buskirk & Crowder 1994). These may be spread over long drawn-out periods or compressed into short seasons when weather conditions are optimal (Miller 1997). In the Arabian region hawksbill turtles deposit multiple clutches and nest during short summer season, typically between April/May and July (Ross & Barwani 1982, Miller 1989, Pilcher 1999, Mobaraki 2004, EAD 2007). But because many monitoring programmes are short and not all nests per turtle are counted, it is unknown what the total reproductive potential of the species comprises in the Arabian region. This sort of reproductive output data at a regional level would provide an understanding of population robustness and would allow managers and conservationists to track population performance over time. If foraging grounds deteriorated and turtles were not able to assimilate sufficient nutrition to develop large quantities of eggs, nesting frequency may drop as a consequence. Similarly, if foraging material is plentiful, turtles are likely to nest more often, and more frequently.

Project efforts to determine total potential reproductive output per turtle were based on deployment of the transmitters as early as possible in the season, and then estimating the time spent in the vicinity of the nesting grounds prior to purposeful migration to feeding grounds. While this may appear somewhat arbitrary, nutritionally-challenged turtles are unlikely to stay in internesting waters where feeding may be further constrained than at foraging grounds. The number of two-week periods (based on known renesting intervals for hawksbills in the region) were calculated along with how many of these fit the time period prior to migration. Based on detention periods in internesting grounds following PTT deployment, it was estimated turtles could potentially deposit up to five additional clutches (for a total of six), but that the norm was for turtles to deposit an average of three clutches per season. These findings are consistent with earlier saturation tagging in Saudi Arabia (Pilcher 1999, Al-Merghani *et al.* 2000) and the short seasons experienced by most nesting sites in the region. Turtles from Oman deposited one to two fewer clutches on average than those in the Gulf.

4.3 MIGRATION BEHAVIOUR

Migration patterns and speeds were compared to typical water movement patterns in the Gulf and in the Gulf of Oman along the Omani coast. Water circulation patterns in the Gulf are typically not strong and average only 0.1 km/h when waters flow southwards in the west, and up to 0.36 km/h when waters flow into the Gulf in the east. These were considered of little consequence to post-nesting migrations of turtles within the Gulf itself due to the slow speeds and known swimming ability of turtles.

Gulf turtles generally migrated to foraging grounds at a speed of around 18 km/day, which is comparable to swim speeds recorded at various other global sites. It appears that the smaller body size of hawksbills in the Gulf did little to influence their swimming ability. Interestingly, most migrations were to the southwest and to the south, with only the occasional turtle headed north, and not eastward. The project team had originally postulated that the east side of the Gulf would be a key destination for hawksbills given the Gulf's reverse estuarine circulation which provides an influx of clean seawater from the Indian Ocean in a counter clockwise direction, but notably not one single turtle headed towards the Iranian coast or the eastern reaches of the Gulf. In contrast, the turtles oriented towards the shallower SW corner of the Gulf which experiences extreme temperature fluctuations and temperature extremes reaching 37°C (John *et al.* 1990).

Outside of the Gulf, ocean currents along the Omani coast are strongly influenced by the summer monsoon, and shallow waters (<150 m) of the Somali current travel in a northeast direction up the Omani coast during June to September, the same time frame when most of the turtles were migrating in an opposite southwest direction. Flow velocities by the Somali current normally average 2-3 m/s and can exceed 3.5 m/s (12.6 km/h), and the larger Omani hawksbill turtles during this study were tracked swimming at 18 km/day or 0.75 km/h against the current. These speeds are comparable or greater than speeds recorded at other global sites and it appears the Somali current had little impact on the turtles' swimming ability, even given their general perception as the 'more sedentary' of Cheloniid species (Wyneken 1997).

No major migratory bottlenecks were detected in the Gulf, but the bottleneck at Ras Al Hadd was deemed a major concern for Oman turtles given the extensive artisanal and commercial fishing in the area. All except for one turtle from the Daymaniyat islands rounded Ras Al Hadd and headed SW to Masirah and beyond, and this area be considered as a critical pathway for turtles in the region. Similarly in Oman the area between the southern tip of Masirah island and Shannah on the mainland is an important migratory pathway and foraging ground.

4.4 SUMMER THERMOREGULATORY MIGRATIONS

Hawksbill turtles which reside in the Gulf experience wide temperature fluctuations and extreme summer temperatures which exceed, over sustained periods, those found anywhere else across their global range. Sea turtle internal body temperatures largely dictated by that of surrounding environment which influences many aspects of their biology. For example, elevated temperatures can lead to biased sex ratios (Hawkes *et al.*, 2007), temporal shifts in nesting seasons (del Monte-Luna *et al.*, 2012), and impacts to developing embryos (Hamann *et al.*, 2007). Concerns have been raised over sea turtles' ability to adapt to elevated ambient temperatures with climate change and projected increases in ambient temperature (e.g. Fuentes *et al.*, 2013), although small increases in temperatures can be (at least partially and targeting specific factors) beneficial depending on species, such as increasing hatchling swim speeds (Booth & Evans, 2011) and growth rates (Diez & Van Dam, 2012), and improving incubation success (Webber *et al.*, 2011).

A substantial body of literature exists on the physiological impacts of hypothermia (being too cold) on sea turtles (Spotila *et al.*, 1997; Milton & Lutz, 2003) and there is evidence of turtles emigrating from colder waters (e.g. Lazar *et al.*, 2003) but surprisingly little is known on impacts of hyperthermia (being too hot). The Gulf experiences some of the hottest water temperatures on the planet during summer months (John *et al.*, 1990) and weekly average sea surface temperatures during this study exceeded 30°C during a surprising 35.4% of all 168 weeks of the study, with a maximum average weekly temperature of 33.8°C. Maximum temperatures averaged over each week during this study ranged from 23.0°C in the winter to 34.9°C in the summer. Milton & Lutz (2003) suggest hyperthermia would be a rare phenomenon for sea turtles, but the Gulf appears to be that exceptional habitat where hyperthermia is a condition hawksbill turtles experience frequently. No data exists for hawksbill turtle temperature tolerance limits and impacts of increasing ambient temperatures, or their ability to regulate changes in temperature under these extreme conditions.

Green turtles also inhabit the Gulf in large numbers and limited information suggests only a small proportion of these turtles emigrate from the Gulf on a temporary basis (EAD, 2007) therefore large numbers must be resident in the Gulf during the same warm summer months. While green turtles are larger than hawksbills and may be somewhat more tolerant to thermal stress (Paladino *et al.*, 1990), it is necessary to conduct further tracking studies to reveal if they display similar behavioural responses as hawksbills.

Given the close relationships between temperature and physiological performance, species survival and global distribution are governed by temperature gradients, and the thermal tolerance of many organisms is proportional to the magnitude of temperature variation they experience (Calosi *et al.*, 2007). Because sea turtles are cold-blooded, they are likely to be more vulnerable to climate warming than other organisms because basic physiological functions such as locomotion, growth, and reproduction are mostly influenced by environmental temperature (Deutsch *et al.*, 2008). What's more, thermal tolerances are likely to be more restricted at the tropics (where hawksbill turtles are found) than at higher latitudes given they are already living close to their optimal body temperatures (Deutsch *et al.*, 2008).

Exposure to high temperatures may reduce reproductive success and endanger populations, influence catalytic efficiency of enzymatic reactions, respiration and osmoregulation and just about every aspect of a species' performance and behaviour. Because feeding activity and digestion / energy budgets are temperature dependent, metabolic rates, growth and physiological maintenance are also impacted by elevated temperatures (Bennet & Dawson, 1976). In addition, survival, reproduction, and growth are governed by the rate at which organisms acquire, process, and transform energy, which is largely determined by body size and temperature. In sea turtles large body size is generally seen as a contributor to thermal tolerance (Paladino *et al.*, 1990), but adult Gulf hawksbills are amongst the smallest in the world, presumably linked to thermal limits and fluctuation rate stressors (Pilcher, 2000). The combination of small body size and elevated temperatures are likely to elevate levels of physiological stress, driving behavioural responses such as those we uncovered in this study.

Hawksbill turtles which reside in the Gulf experience wide temperature fluctuations and extreme summer temperatures which exceed, over sustained periods, those found anywhere else across their global range. Exacerbating these impacts, the vast majority of electrical power generation and desalination plants in the Arabian region are water-cooled, producing high-temperature, high-chlorine effluents at localised levels. These localised high-temperature zones further impact turtles at the local level and potentially drive them from resident foraging grounds. It is unknown how marine turtles will adapt to long-term regional and local warming of their environments, but these results indicate there are, at least in the short term, thermoregulatory responses which take sea turtles out of high temperature and potentially physiology-threatening conditions. While these newly-found nature-based responses are an adaptation to greater climate variances, it is unknown what the impact of the localised temperature increases will be, but it is suggested at the very minimum that they will drive turtles from traditional feeding grounds without the chance to return when temperatures cool.

These project findings provide an initial look into behavioural responses by hawksbill turtles to elevated water temperatures, and given the extreme temperatures found in the Gulf, this thermoregulatory response highlights a potential adaptive measure by marine turtles to climate change and potentially to elevated sea surface temperatures across other parts of their range. While measurements of sea surface temperature (SST) is a relatively recent phenomenon, records for the northern Gulf indicate the Gulf has always been warm in the summer with an overall steady rise in SST since 1985 at a rate of 0.6°C/ decade (Al-Rashidi *et al.* 2009) and it is likely the response by sea turtles is not a recent development.

4.5 FORAGING HABITATS

4.5a General Descriptions

Ground-truthing of five foraging sites in Abu Dhabi waters indicated that these consisted of extensive sparse seabed areas surrounding single shallow 'hard substrate mounts' dotted with individual coral colonies and small isolated sponge structures. Complementing this, home range and core areas were represented by single or multiple small 'seamounts' or shallow areas where sparse corals and reef-associated invertebrates settle. Interestingly, individual foraging habitats were not directly linked to major coral structures as identified during earlier coral surveys in the Gulf. The surveys determined that the peripheral areas to each of the primary 'reef' foraging areas were predominantly devoid (if not completely barren) of any other major macrofauna which could constitute foraging material for the turtles. Key areas used by hawksbill turtles were typically only 5-10 m deep. Other than the impacts of fishing noted at Sir Bu Nair, no other man-made damage was obvious, although anchor damage was noted at several sites.

Hawksbill turtles primarily feed on sponges (Meylan, 1988) which in turn are reliant on primary productivity as filter feeders. The small size of the Gulf precluded any substantive conclusions from sea surface level and currents, although neither of these appeared to drive the temporary emigration from foraging grounds, and similarly there was no correlation between turtle location in time and space and Chlorophyll-a levels. The fact that turtles generally returned to the same or similar foraging habitats suggests the migrations were not catalysed by specific local conditions or pressures, and it is far more likely that temperature and not currents or sea level height were the driving force behind the temporary emigrations into deeper waters.

Growth and reproduction are integrally linked to foraging ecology (Bjorndal 1997) and limitations to foraging or food availability can impact the productivity of individuals and populations. Similarly, exposure to temperatures which exceed normal tolerances can lead to a decrease in nutritional uptake and growth. Gulf turtles are among the smallest adult turtles worldwide (Pilcher 2000), in comparison to Omani turtles which are an average of 10 cm larger in carapace length as nesting adults, suggesting that growth in Gulf turtles is nutrient-limited. It is noteworthy that Gulf turtles spent >20% of their time undertaking summer migration loops, during which it is unknown if they were actively feeding. The ground-truthing investigations of five known foraging sites revealed no living reef or reef-like clusters at depths >15 m, depths to which turtles migrated during the summer loops. Other studies have revealed infrequent small (<2-5 m^2) reef structures in deeper reaches of the Gulf, and it is possible hawksbills were targeting these sites. If this were so, it would suggest the Gulf hawksbills have the ability to pinpoint extremely precise locations. While this phenomenon is known in sea turtles migrating from distant feeding grounds to nesting beaches (e.g. Bowen *et al.* 1995) and from nesting sites to distinct feeding grounds (e.g. Limpus *et al.* 1992), the summer migration tracks by Gulf turtles do not suggest the turtles spent substantial periods at any one particular point except for in a handful of isolated instances.

4.5b Foraging Ground Distribution

Possibly most interesting of all findings were the locations of hawksbill turtle foraging grounds in the Gulf, and the restricted range of those outside of the Gulf. Clean waters enter the Gulf through the Straits of Hormuz and travel in a counter-clockwise direction up the coast of Iran and down past Saudi Arabia, Qatar and the UAE. Extensive and diverse reef development occurs along the Iranian coast, and yet not one single turtle headed in that direction. Nearly all Gulf turtles headed in a south or southwest direction towards the waters of Abu Dhabi and lower Qatar, with only a handful headed north of Qatar to the Fasht (reef) areas north and east of Bahrain, Abu Ali in Saudi Arabia, and Kuwait. Similarly interesting was the manner in which turtles stayed close to the Omani coast during their migrations selecting foraging grounds in just a couple of places.

Turtles in the Gulf spent some 70% of their time on foraging grounds, and Omani turtles spent upwards of 85% of their time in foraging areas. The difference in these two time allocations is the result of Gulf turtles undertaking summer migrations to escape higher surface water temperatures during summer months, during which it was believed they are not feeding. The foraging habitats were spread over vast areas but at the individual turtle level they typically ranged over only 40-60 km^2 with core areas of only 3-5 km^2 in size. In the SW corner of the Gulf foraging grounds are distributed across ~20,000 km^2 between Abu Dhabi in the UAE, a small parcel of Saudi Arabian territorial seas, and the southern reaches of Qatar. In Oman the foraging habitats are spread along >500 km of coastline, but given the steep deepwater drop-off close to the Omani coastline their habitats are restricted to a narrow coastal belt. In addition to this, the coastal area is predominantly shifting sands with little reef or hard substrate (Pilcher *et al.* 2000) in the form of suitable foraging habitat for hawksbill turtles.

The ground-truthing surveys determined that the peripheral areas to each of the primary 'reef' foraging areas were predominantly devoid (if not completely barren) of any other major macrofauna which could constitute foraging material for the turtles. These areas were typically over 10-15 m in depth, and areas with coral and other invertebrate growth were typically recorded at 5-10 m depth. Interestingly, individual foraging habitats were not directly linked to major coral structures (Figure 17) as identified during earlier coral surveys in the Gulf (Riegl *et al.* 2008).

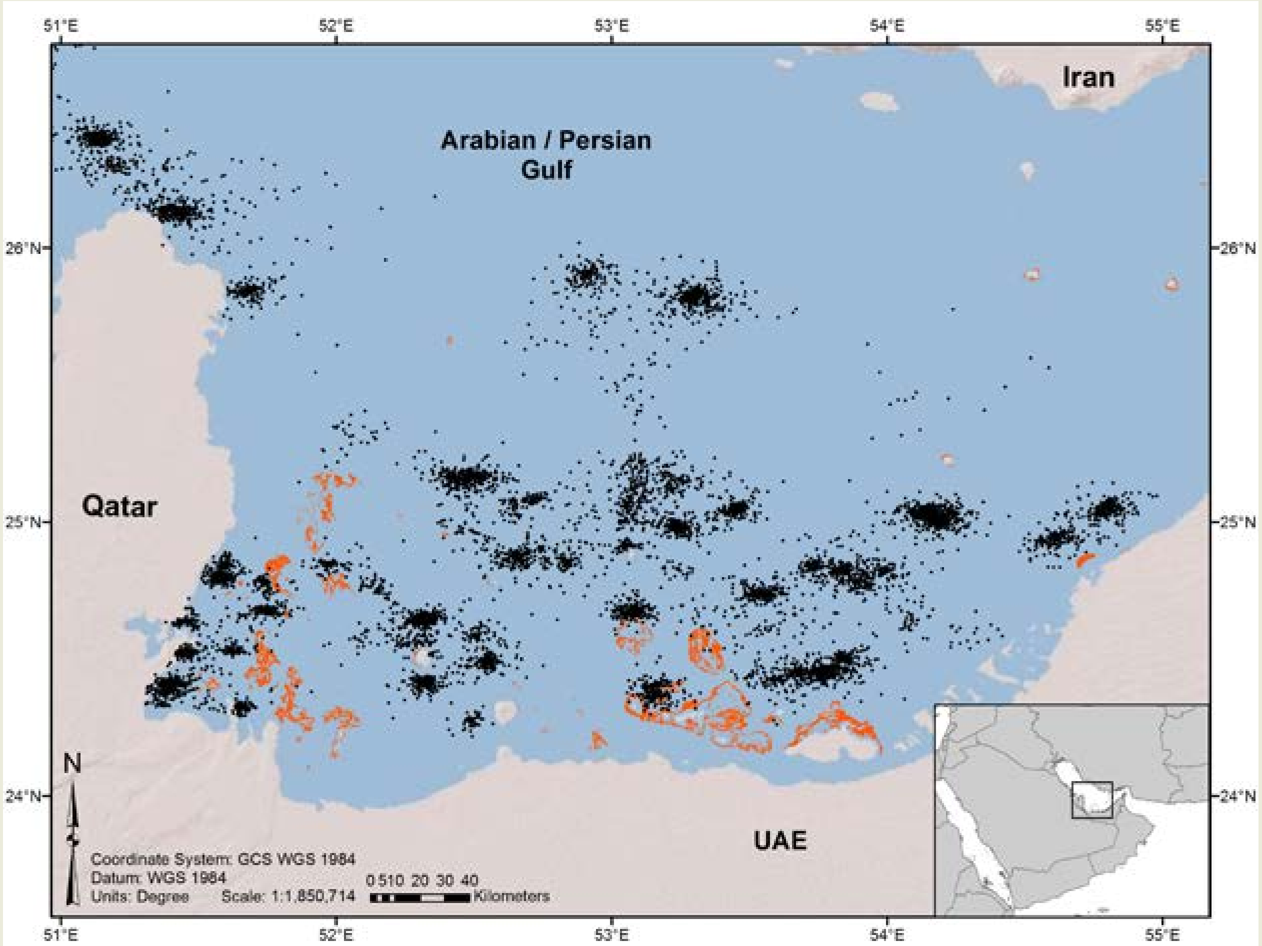

Figure 19: Locations of individual hawksbill turtle foraging grounds in the SW corner of the Gulf (black dot clusters) which do not generally correspond with major coral reef areas (orange shading).

The project findings indicated home ranges and core areas (Figure 18) for Omani turtles were substantially smaller than those for Gulf turtles, suggesting Oman turtles have access to higher quality foraging areas than those turtles living in the climate-challenged Gulf, resulting in a decreased requirement for wide-spread foraging movement. In addition, recent investigations of corals in the Gulf point to decreases in reef quality with decreases in coral cover, survival and species diversity (e.g. Reigl 1999, Wilson *et al.* 2002), while Indian Ocean conditions appear to have escaped these declines (Wilson *et al.* 2002). The smaller foraging ranges may help explain the larger size of Oman hawksbills as greater proportions of nutrient intake can be invested in growth rather than foraging displacement.

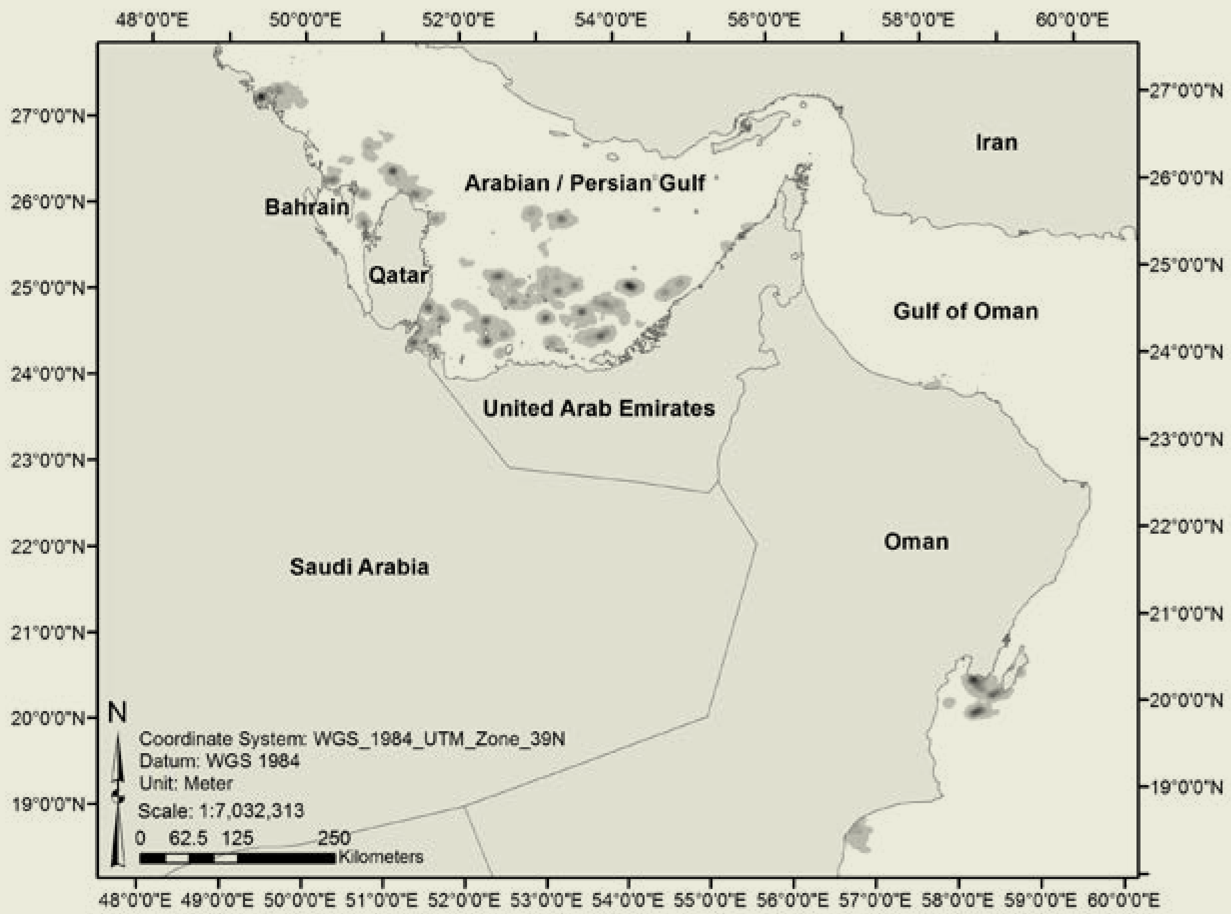

Figure 20: Home range density plot of foraging areas. Darker areas represent a higher density of turtle locations,

Of the 25 turtles deployed in Oman, only one (Tag ID 53003) migrated into the Gulf, with the balance all headed towards Masirah and further south, notably at two key foraging areas which warrant consideration for protection. This is the first confirmed migration of a hawksbill into the Gulf from the Gulf of Oman but it is suggested this is likely not a common occurrence. Indeed, given the reduced foraging range quality available to turtles in the Gulf, it is reasonable to expect turtles from Masirah to stay in the Gulf of Oman or other Indian Ocean sites. That said, recent work has documented the ingress of several loggerheads from Oman and a second hawksbill into the Gulf (MECA, unpublished data) conformed by captures of live loggerheads off Qatar (Pilcher, unpublished data), and while these represent a small proportion of all tracked turtles out of Oman, the additional migrations further confound the issue.

4.6 IMPORTANT TURTLE AREAS (ITAS)

Turtles at sea are prone to a suite of vastly different pressures than those they face as they approach beaches to lay eggs. Fishers (both legal and illegal) stand in their way. Pollution from an ever-growing industrial base threatens with oil spills and direct impacts to foraging habitats. Climate change can impact the quality of the forage material. Given turtles spend over 95% of their time at sea, understanding the location and extend of their foraging grounds and areas where they reside for substantial periods, and impacts to these, are critical for conservation action to be effective (Figure 20) . Following similar approaches to identify important foraging and breeding areas for birds (IBAs – or Important Bird Areas), these key areas have been named Important Turtle Areas to focus management actions and conservation priorities.

This project identified two key sets of Important Turtle Areas:

- Foraging ground assemblages off Oman and in the SW Gulf
- Summer migration hotspots in the central Gulf. This area is time-sensitive, in that the turtles are only in these areas during July, August and September, while the foraging grounds are inhabited year-round.

Along with these important areas is also one significant migratory bottleneck at Ras Al Hadd, via which all Masirah turtles migrate on their way south.

The tracking data for turtles in the Gulf revealed that turtles undertaking migration loops spent roughly half their time actually swimming between resident foraging grounds and temporary summer residences, with the remaining half spent in temporary habitats. These temporary habitats differed substantially and distinctly from primary foraging grounds, and the distinction is important because now two key areas are of concern when considering turtle conservation in the Gulf. Turtles during the summer migrations inhabited deeper waters (20-50 m) than ground-truthed foraging sites (5-7 m) and an average of one degree of latitude further north. After the removal of extremely widely dispersed location fixes during outbound and return migrations, the core areas representing >50% of summer loop location fixes have been used to focus conservation attention (Figure 21).

In Oman the identification of Important Turtle areas was substantially clearer, with the identification of Shannah and Quwayrah as being key foraging habitats, and the waters off Ras Al Hadd – indeed the 20 km band along the shores between Daymaniyat, Muscat and Masirah – constituting an important conservation bottleneck for hawksbill sea turtles.

4.7 THREATS

During this time turtles are prone to two key anthropogenic threats: fishery bycatch and shipping. Small-scale artisanal fisheries have the potential to inflict severe negative impacts on in sea turtles (Lewinson *et al.* 2011).

Incidental capture by net fisheries targeting other species is the biggest threat to many populations of long-lived marine vertebrates such as sea turtles, sharks and rays, inshore cetaceans, and sirenians (dugongs) (Lewinson *et al.* 2011). Gillnets have been identified as a particularly hazardous fishing gear due to their relatively cheap purchase and operational costs, typically large size, the nature of their material and the long 'soak times' which increase the likelihood of drowning for these obligatory air-breathing animals. Many of these species are also experiencing additional pressures (such as loss of habitat or targeted fisheries) which, when combined with the characteristic life history of long-lived vertebrates, may result in even low levels of incidental bycatch having a serious impact on a declining population. Based on anecdotal evidence, gill nets are banned in several Gulf countries but continue to be widely used. Ironically, where the use of gillnets is banned, they are easily purchased on the open market. No Gulf countries have implemented permanent fishery observer programmes (except for recent developments in Oman) and thus there is a scarcity of data on 1) where small-scale vessels fish; 2) levels of fishing effort; 3) bycatch rates for large marine fauna; and 4) hotspots where large marine fauna are encountered. These data are urgently needed at National levels which may, when overlaid with turtle habitat hotspot data, paint a picture of regional conservation hotspots.

Similarly vessel traffic is a threat to turtles (Hazel & Gyuris 2006). Where ports and shipping traffic intersect with sea turtle nesting beaches, nearshore habitat and ocean migration paths, the potential for harm to or disruption of sea turtle life cycle arises (STRP, 2013). Maritime transportation is the dominant form of international freight distribution and takes place on a global maritime scale. Maritime routes are typically only a few kilometres wide and international maritime routes are forced to pass through specific locations linked to passages, capes and straits. The Gulf experiences some of the highest shipping densities on

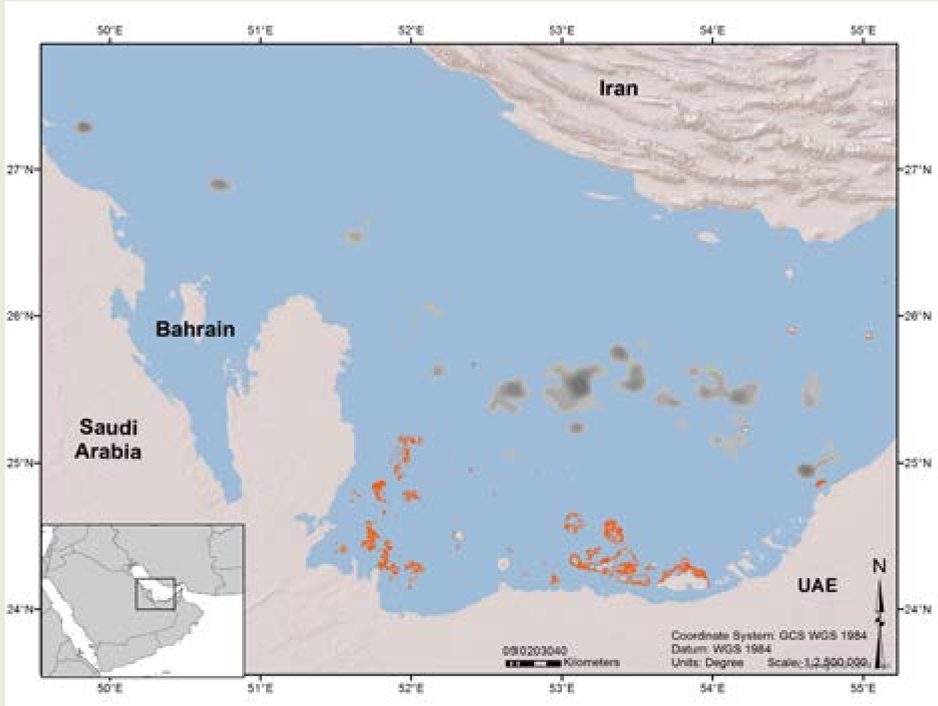

Figure 21: Core areas during the summer migration loops. The lower 50% location data were removed as these represent the outbound and return migration paths, and darker regions indicate higher densities.

the planet, with nearly 40,000 vessels plying its waters in 2012 alone, covering virtually every corner of the Gulf (Figure 22). The Strait of Hormuz adds to the threat level to marine fauna as it forms a narrow strategic link between the oil and gas fields of the Gulf and the Gulf of Oman and Indian Ocean. It is roughly 50 to 80 km wide, but navigation is limited to two 3 km-wide channels, each exclusively used for inbound or outbound traffic. Some 17 million barrels of oil are transported through the Straits on any given day aboard some 14-15 tankers. This value does not include natural gas shipment, or general cargo, so the number of vessels plying Gulf waters each day rises to several hundred.

Given cargo vessels are restricted to deep water channels, threats to turtles are constrained to these areas. Over a period of two years, some 130 sea turtles were killed by collisions with vessels along the coast of Queensland in Australia, where Hazel *et al.* (2007) demonstrated that slowing ship speeds decreases vessel collisions with sea turtles, but also noted the limitations to this practice with larger vessels. It is unlikely that shipping speed restrictions in the Gulf would be practical (although electronic enforcement would be possible) but it is possible that the development of specific navigation channels as exist within the Straits of Hormuz might reduce the probability of turtle-shipping interactions.

Contrary to earlier expectations that Gulf hawksbills would inhabit clear-cut areas that may be demarcated for some level of protection, the widespread dispersal of hawksbills across the SW Gulf dictates that habitat protection options available to managers will need to be carefully considered. Hawksbill foraging habitats are predominantly located in shallow waters where commercial shipping is less of an issue, but this is also where most traditional fisheries are located. Therefore it is likely that curtailing industrial development in shallow water areas to maximise foraging habitats for hawksbills, an evaluation of fishery activities for their impact to hawksbills, and constrained shipping lanes may substantially improve the conservation outlook for sea turtles in the Arabian region. Regardless of what specific form these measures take, there should be a concerted effort by industry and government to implement best practice guidelines and ensure environmental impact assessments are thoroughly conducted.

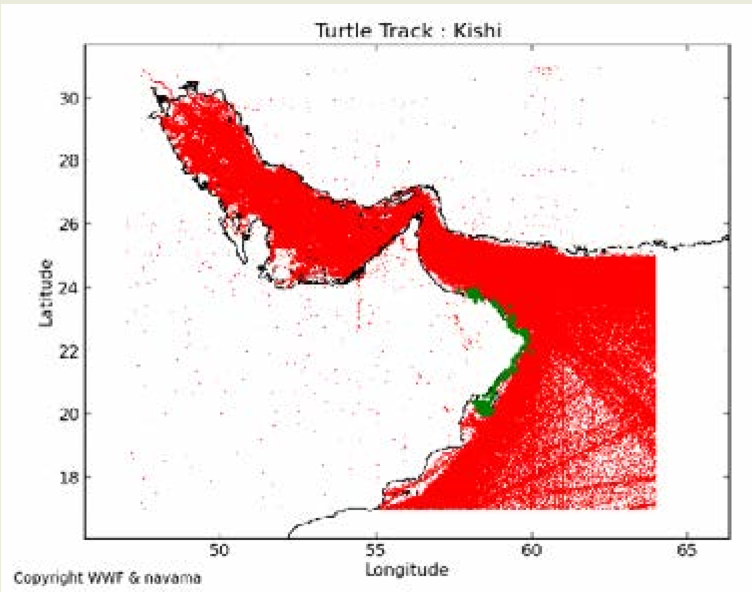

Figure 22: Subset of AIS shipping data for the Gulf, Gulf of Oman and Arabian Sea for 2012. Each red dot is a location fix for one vessel with a total of ~21,500,000 fixes.

5. CONCLUSIONS

The tracks made by a turtle moving along the beach are unique to each species and help in the identification of nests after the turtle has returned to sea.

The results from this project provide the first evidence of temporary summer emigration thermoregulatory responses among Gulf turtles, reveal migration pathways and a critical bottleneck at Ras Al Hadd, the easternmost point of the Arabian peninsula; identify locations of foraging grounds and clustering of these in the SW Gulf and close to Masirah island in Oman, and determine the proportion of time spend at various reproductive biology life stages for critically endangered hawksbill turtles. These data can now inform management agencies and conservation practices in a region home to one of the most climate-challenged marine habitats on the planet, subject also to immense urban expansion, shipping and petrochemical industry pressures, and which supports large nesting and foraging populations or endangered sea turtles.

- Project results demonstrated that hawksbill turtles in the Arabian region likely nest an average of three times and up to a maximum of six times each season, devoting slightly over 6% of their time to nesting activities and a similar amount of time migrating from nesting areas to foraging grounds. They inhabit foraging grounds for about 70% or more of their time.
- Gulf turtles spend around 15% of their time in thermoregulatory summer loops out into deeper and cooler waters. This thermoregulatory response was not noted in Omani turtles, likely as Indian Ocean waters do not experience the severe warming that occurs in the Gulf.
- Turtles in the Gulf occupy important areas in the southwest reaches shared by Abu Dhabi (UAE), Saudi Arabia and southern Qatar.
- Omani turtles migrate further than Gulf turtles, SE from Daymaniyat and then SW along the mainland coast to inhabit a small region close to Masirah island, and a second site further down at Quwayrah.

These results present the first comprehensive understanding of post nesting migrations, foraging grounds and behaviour by hawksbill turtles in the Arabian region. These results will be used by government and conservation agencies in spatial formats compatible with Global Information Systems enabling risk assessments for turtles in the face of urban and industrial development, climate change, fishery pressure, shipping and oil and gas development, and for developing strategic management initiatives targeted at the Important Turtle Areas (ITAs). These risk assessments will further highlight the overlaps between important turtle habitat and the varied threats in the Arabian region (sensu Grech & Marsh 2007) and provide a pathway for prioritising Important Turtle Areas for dedicated conservation and management action. Given the opportunities which exist for the use of these sorts of information, such as the development of Marine Protected Areas (Schofield *et al.* 2013), the project team envisions these data supporting the designation or expansion of existing protected areas to safeguard the various marine life stages of turtles, and build on the current wide spread protection of turtles at their nesting sites.

With this newfound understanding of turtle habitat use in the Gulf and temporary displacement during summer months, coupled with the widespread distribution of turtles throughout the SW basin of the Gulf, management and conservation strategies will need to be flexible and adaptive. It will also need to draw on exiting marine area protection, fisheries management and shipping regulations, industrial activities and coastal and sea-bed modification and development, while adapting these to the hawksbill turtle spatial and temporal movement patterns. These new findings may be used to identify important areas for hawksbills in the Gulf, and we hope these findings will accelerate the consideration of additional protected or managed marine areas and measures which will provide refuge to marine turtles at their varied life stages.

5.1 Potential Conservation / Management Areas

Conservation of marine areas presents vast challenges. They are often remote, problematic to delineate and regulate, and access is often limited given logistics of maritime travel. Confounding this marine species are not confined to small areas but rather spread over large areas which often prove impractical to conserve. And yet conservation of habitats to protect individual species have shown great promise in recent history. Australia's Great Barrier Reef World Heritage Site, alongside the Papahānaumokuākea Marine National Monument in Hawaii, USA, are among the world's largest marine reserves, and examples of large marine areas which protect key marine megafauna. While protection of the lower SW corner of the Gulf is potentially feasible and would be able to address fishery pressures, the international nature of shipping that takes place through these waters might prove more problematic. Regional collaboration will be required which overcomes political boundaries and National jurisdictions for such a measure to come into effect. However, at the National level, the following areas are potential considerations for conservation:

- In Iran, the internesting areas surrounding Sheedvar and Busheir nesting areas;
- In Oman, the waters between Masirah and the Omani mainland, and the waters off Quwayrah;
- In Qatar, the waters off the NE coast between Ras Riken and Fuwairit, the waters surrounding offshore reef areas to the east of Doha, and the waters off Khor Al Udaid in the South; and,
- In the United Arab Emirates, an expansion of the Bu Tinah – Marawah Biosphere Reserve to include the waters down to Abu Ali Abyad and westward to the Saudi Arabian border.

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ANNEX A

TRACKING MAPS OF EACH INDIVIDUAL TURTLE BY COUNTRY.

Iran

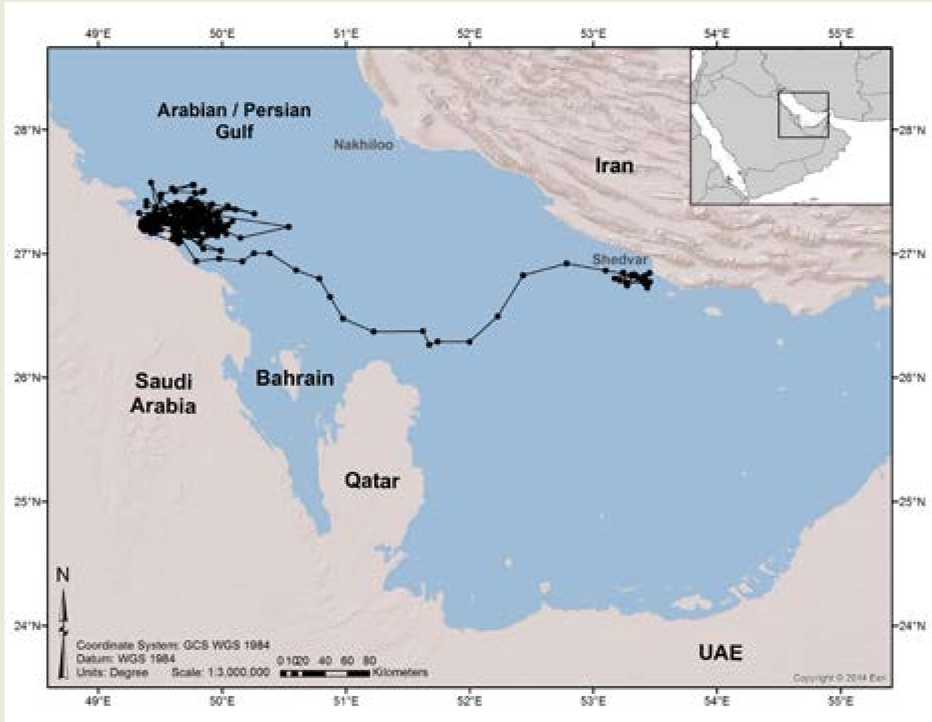
Oman – Damaniyat Islands

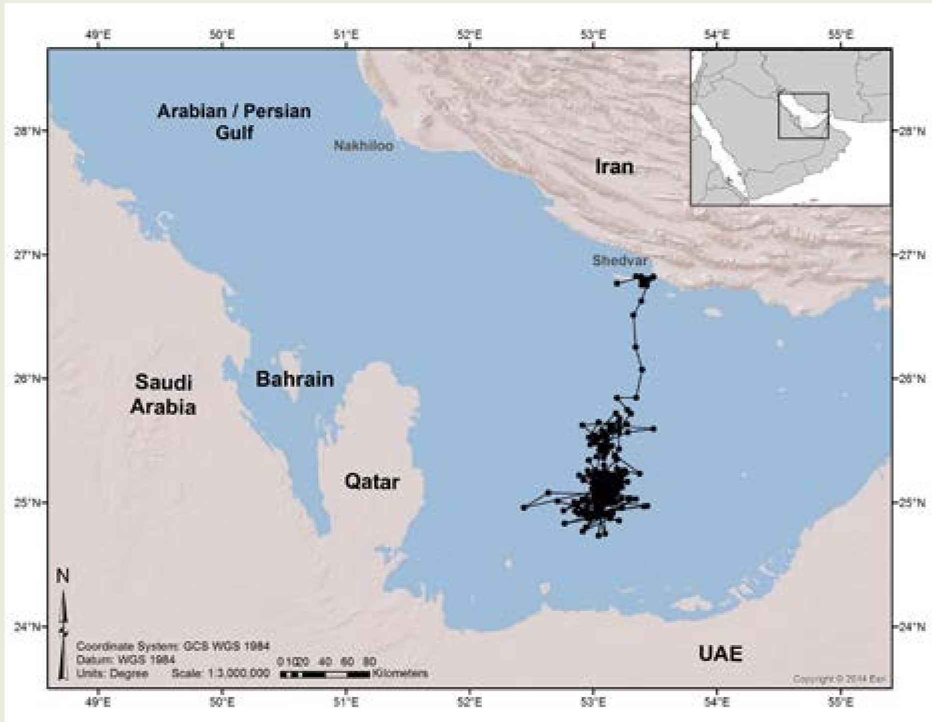
Oman – Masirah Island

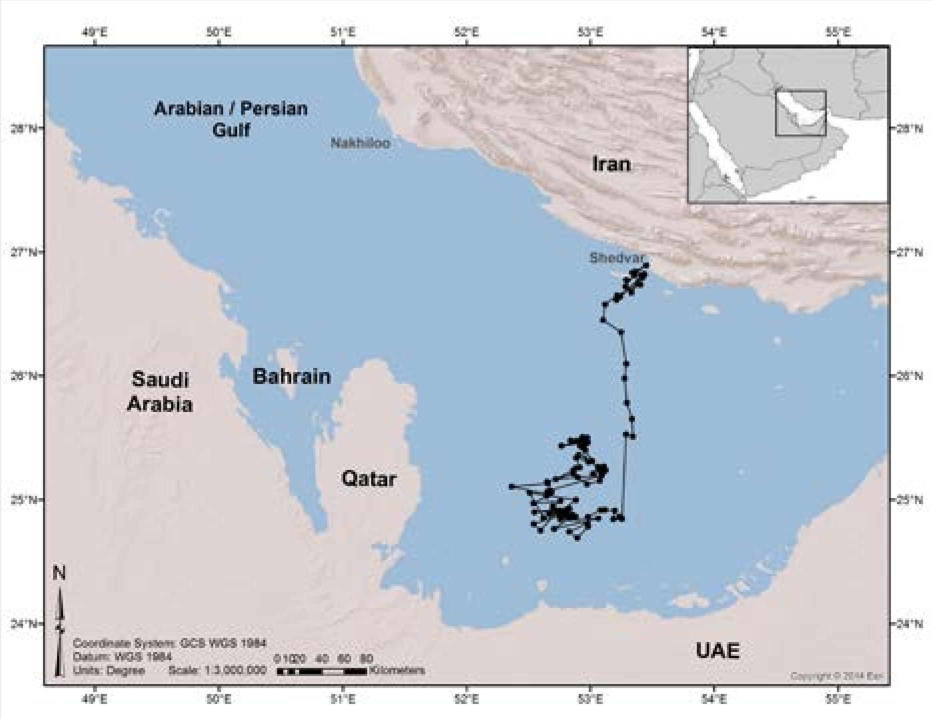
Qatar

United Arab Emirates

IRAN



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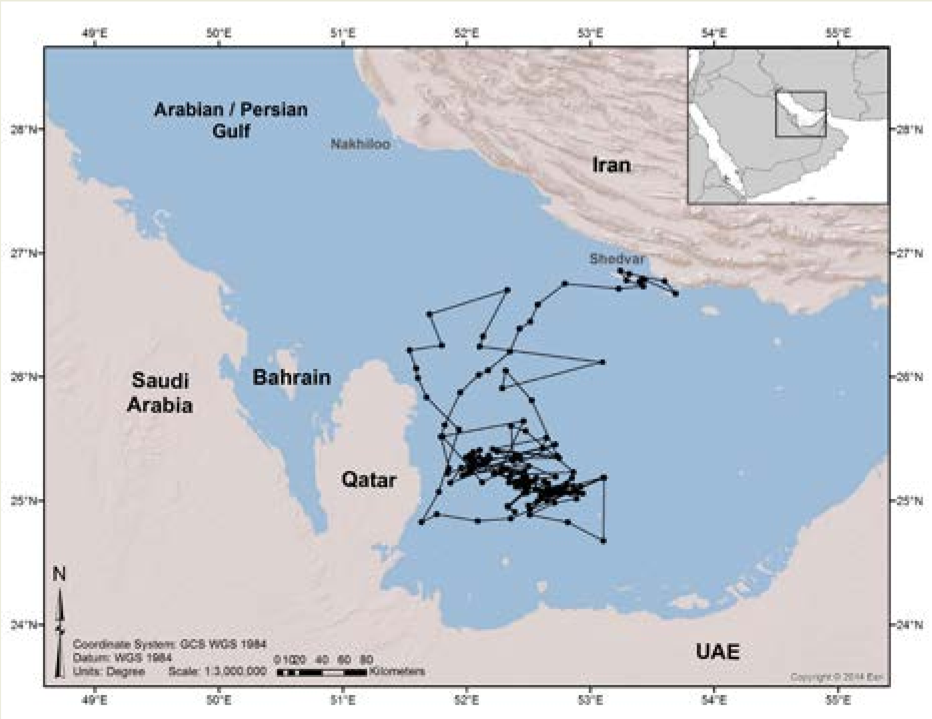
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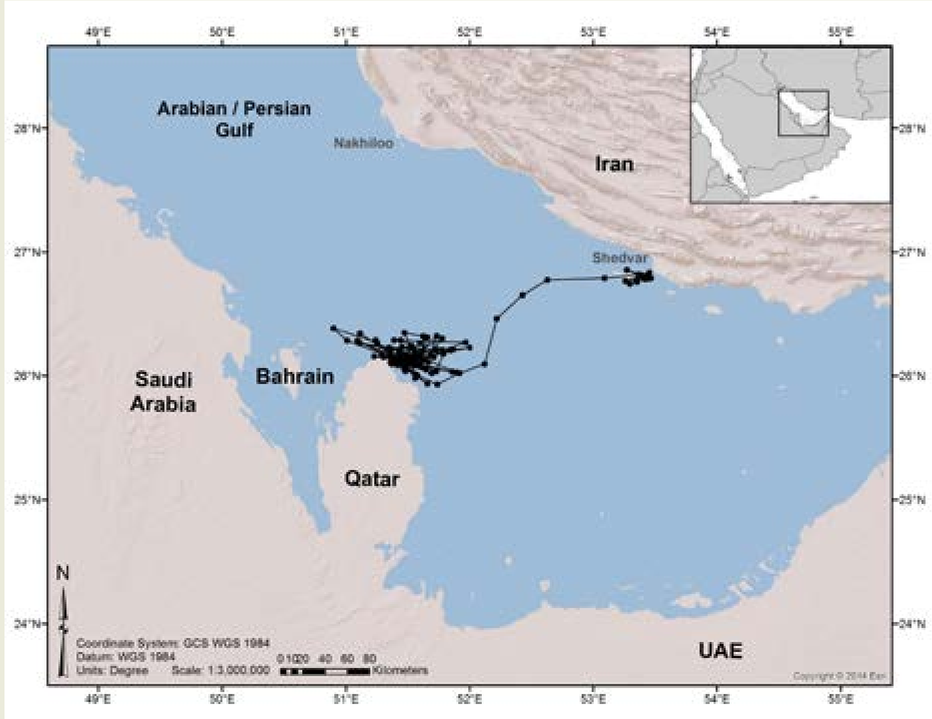
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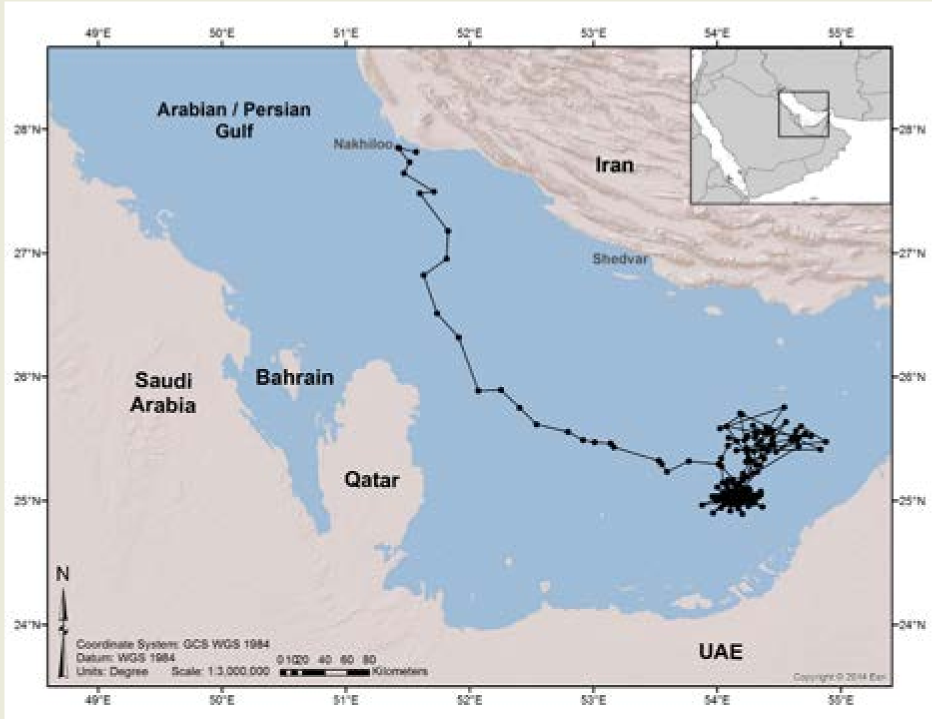
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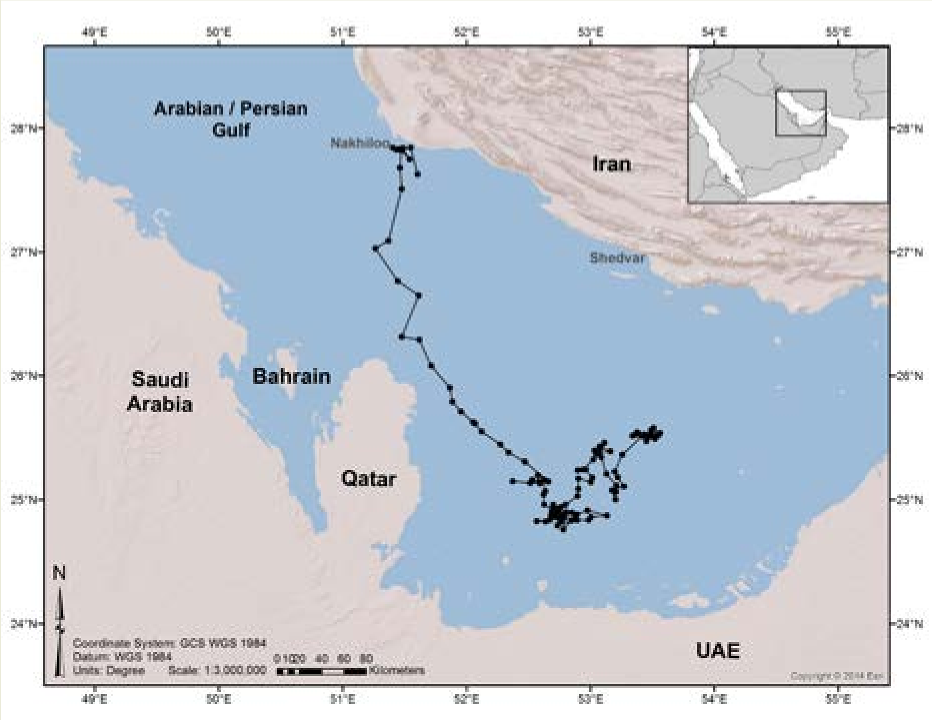
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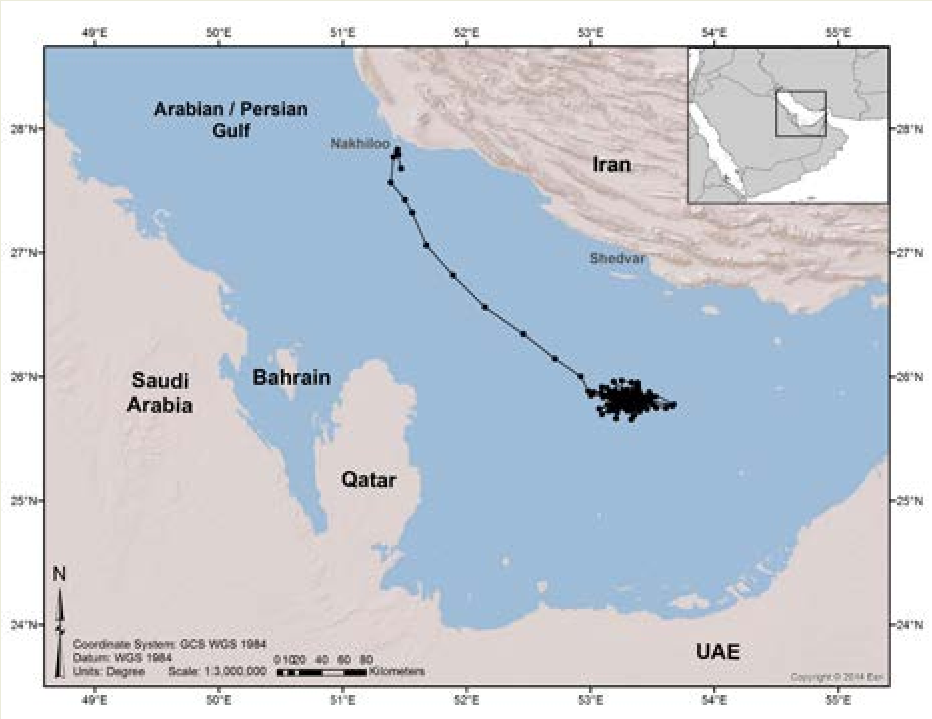
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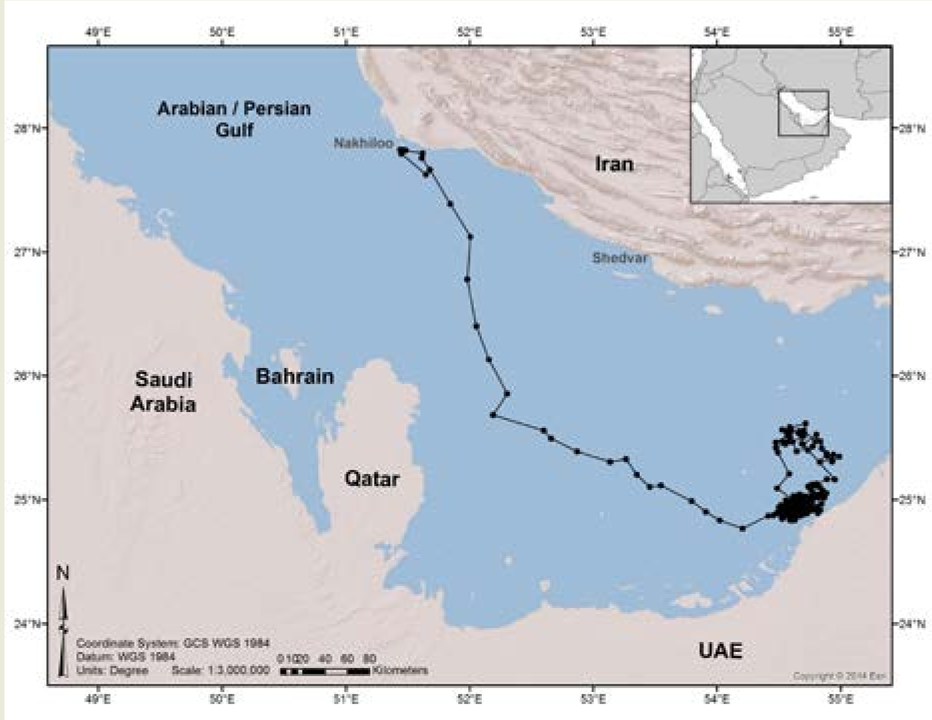
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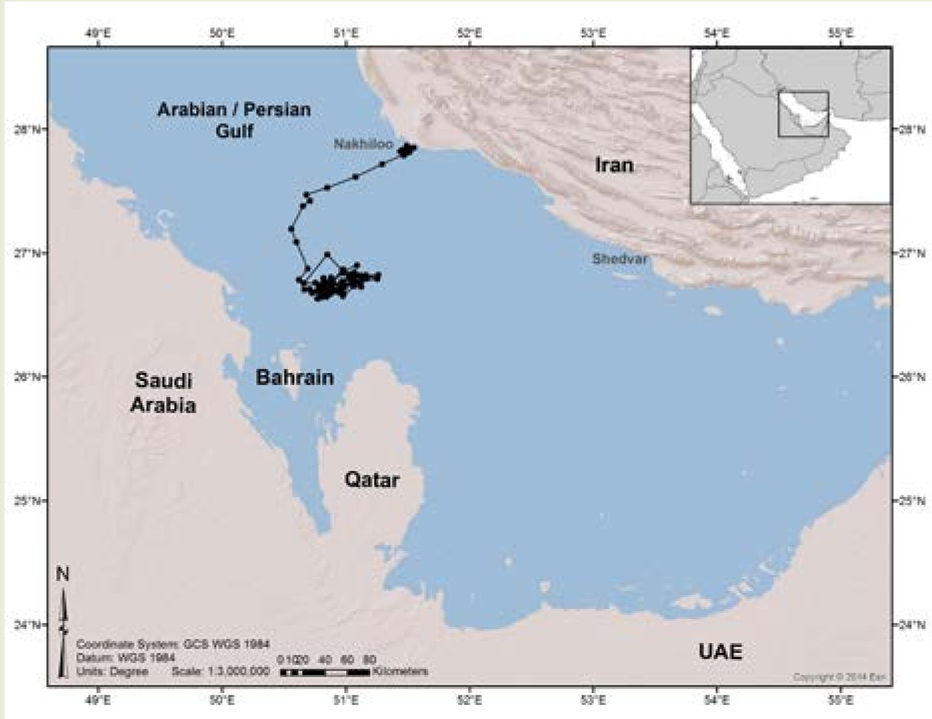
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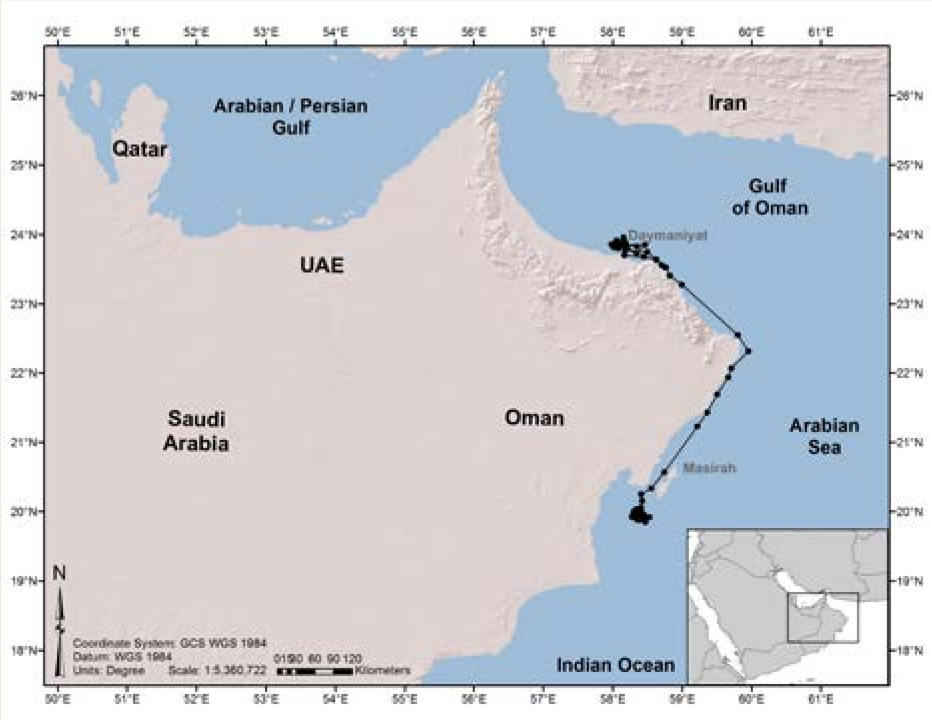

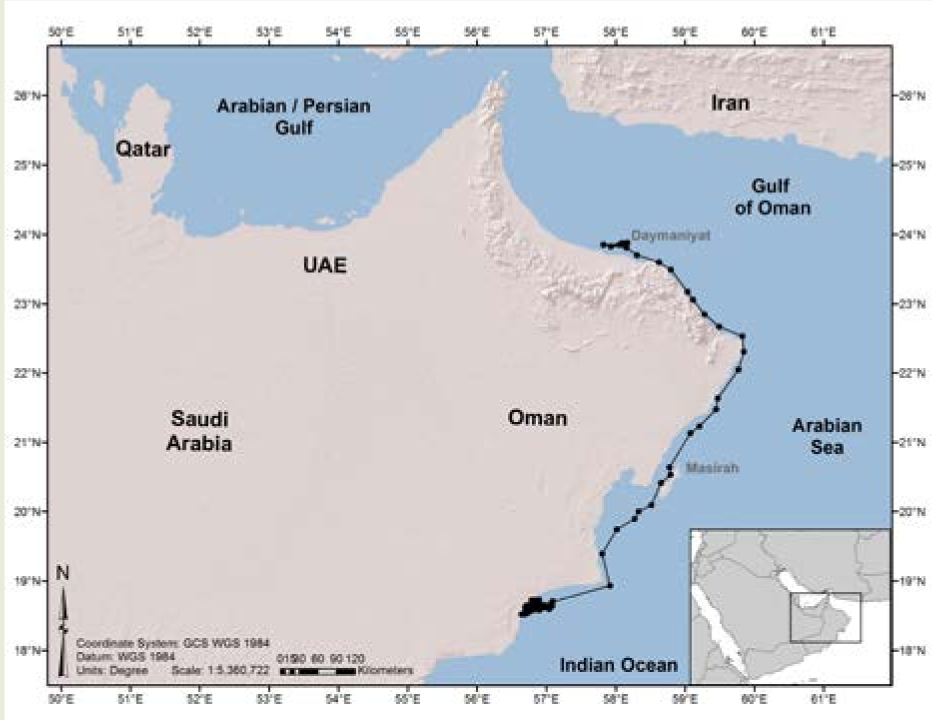

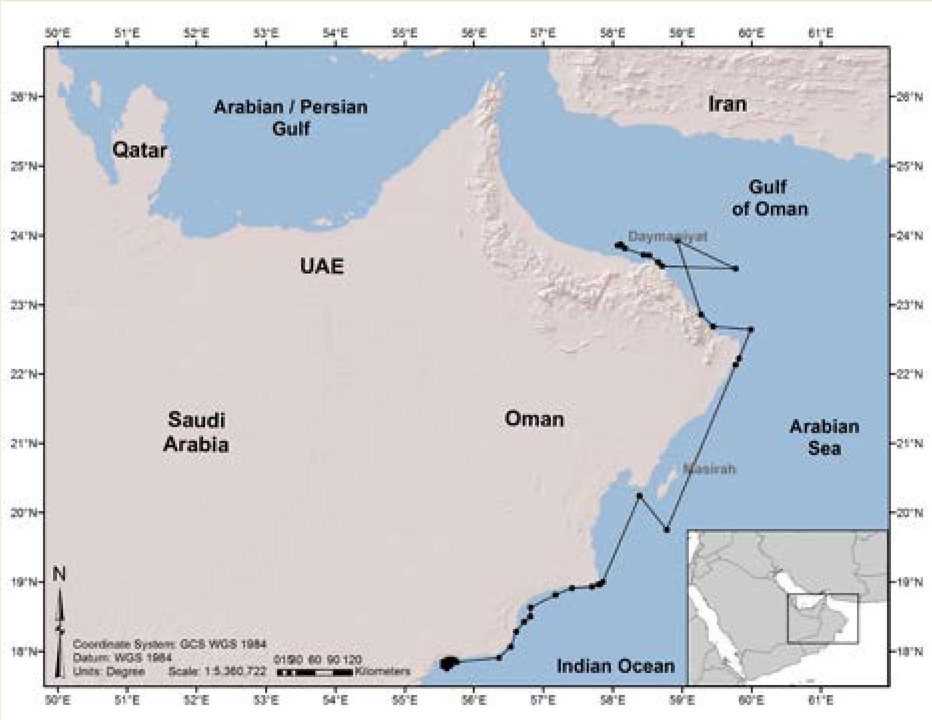

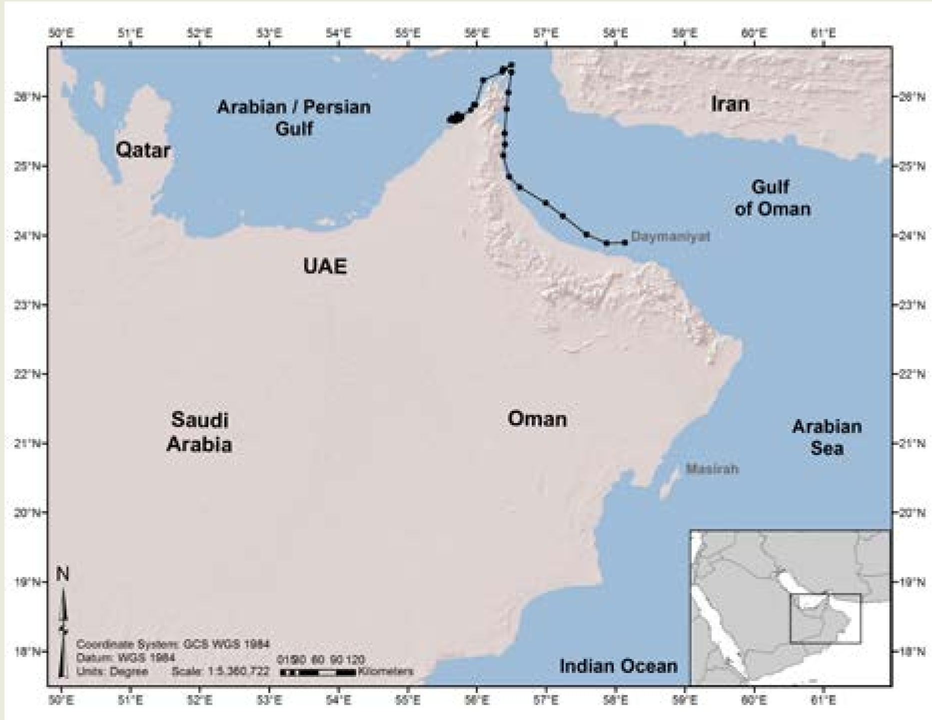

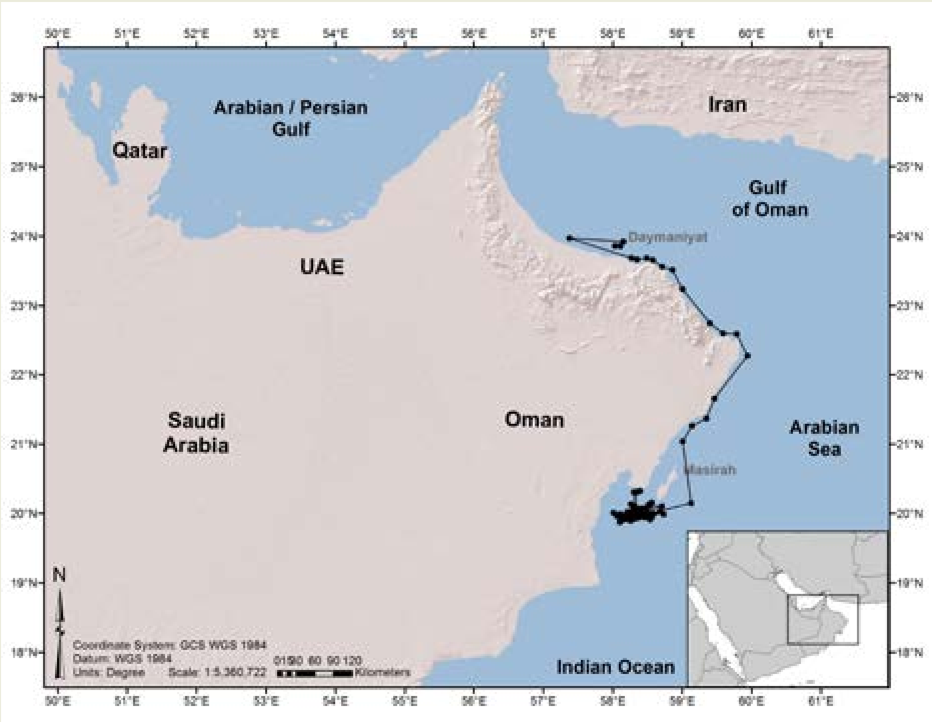
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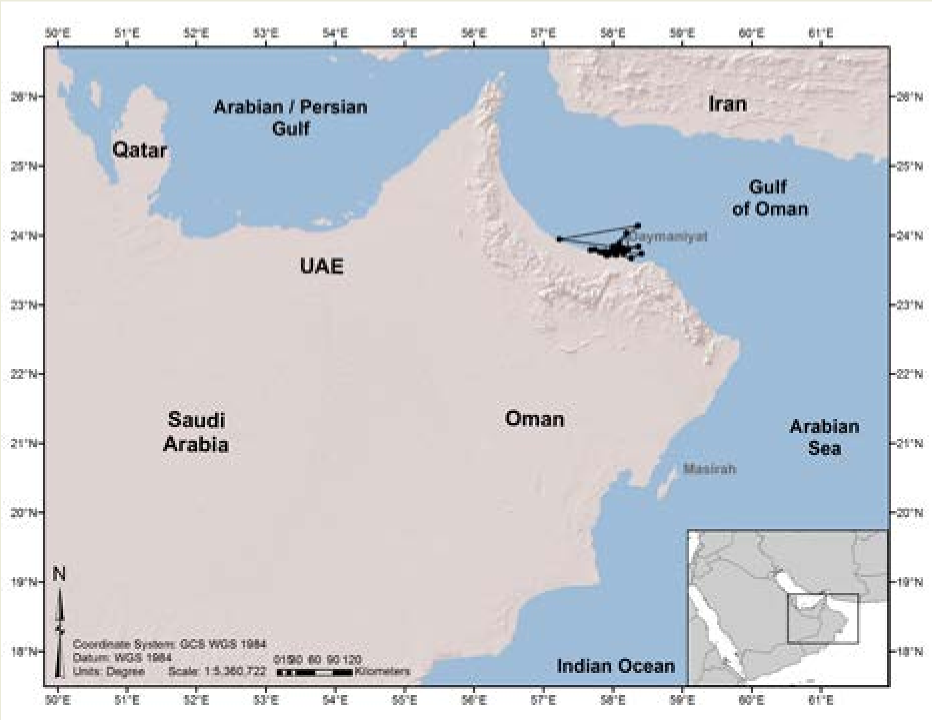
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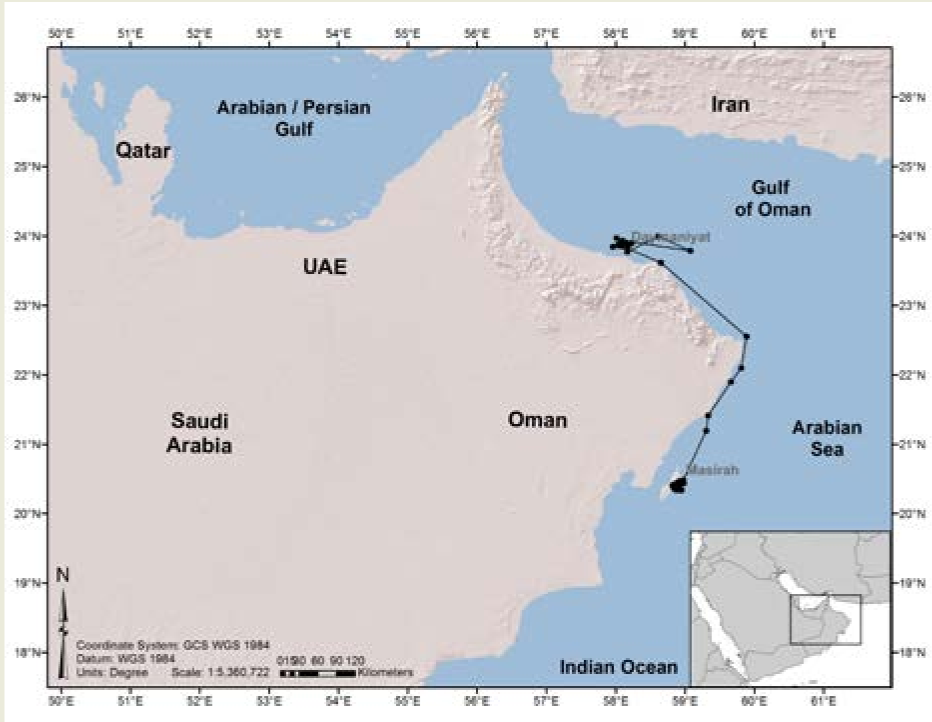
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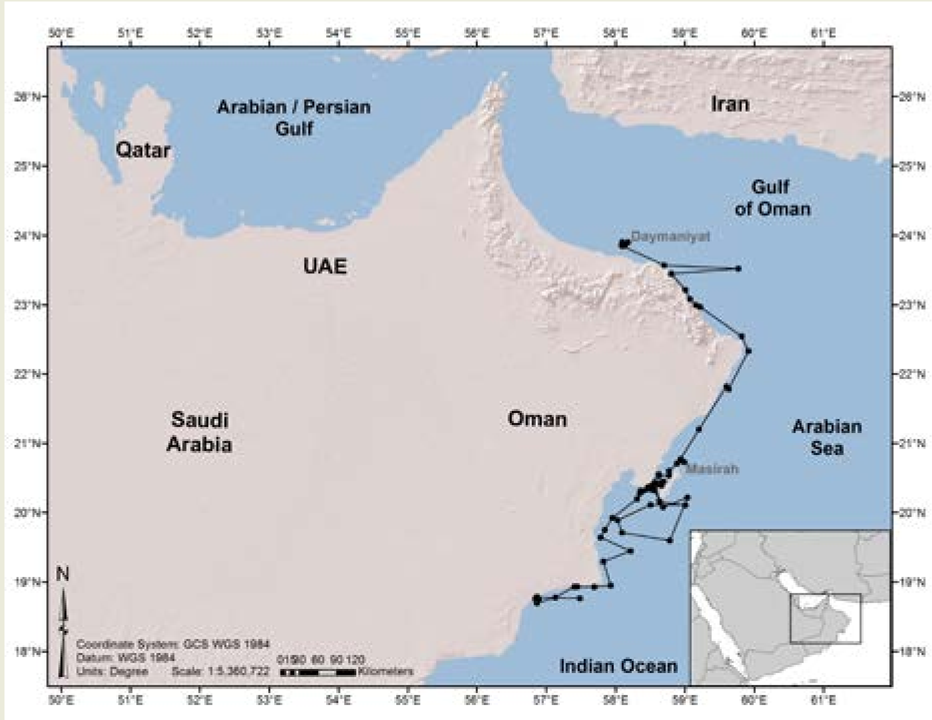
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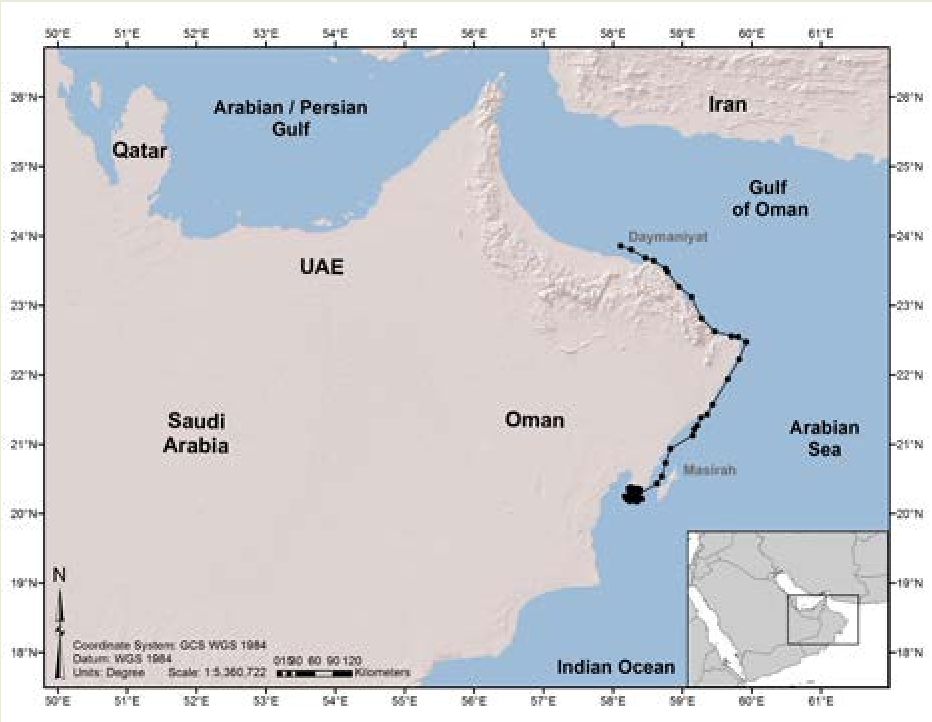
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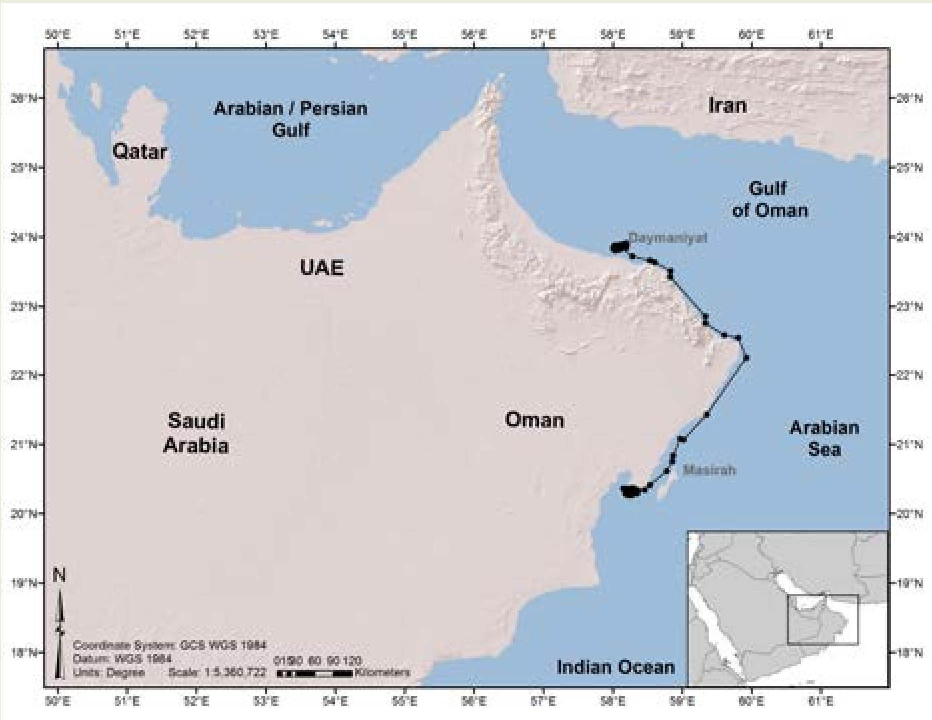
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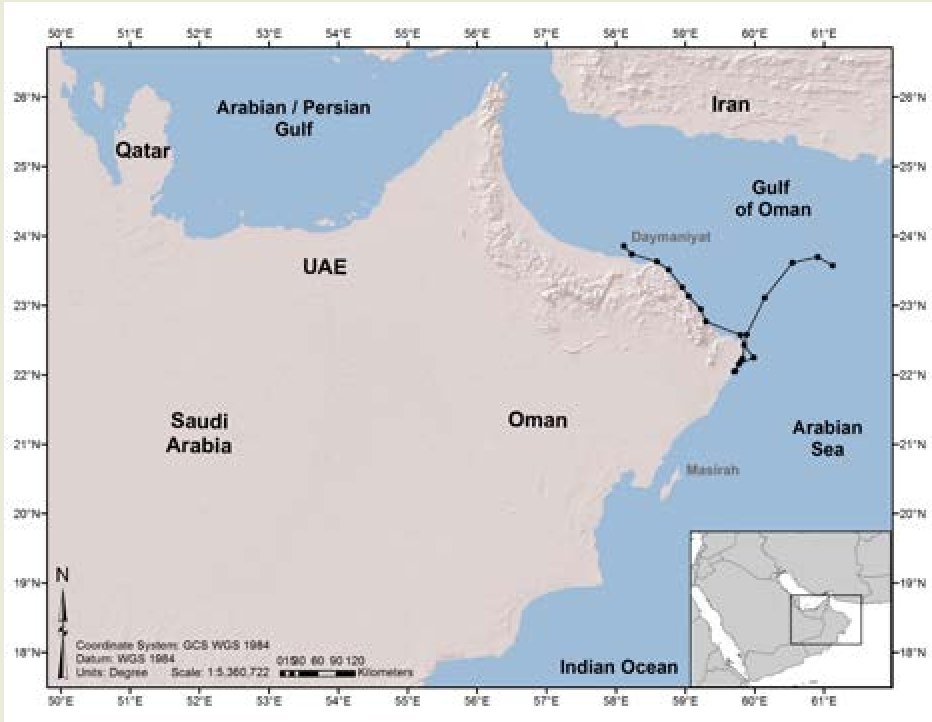
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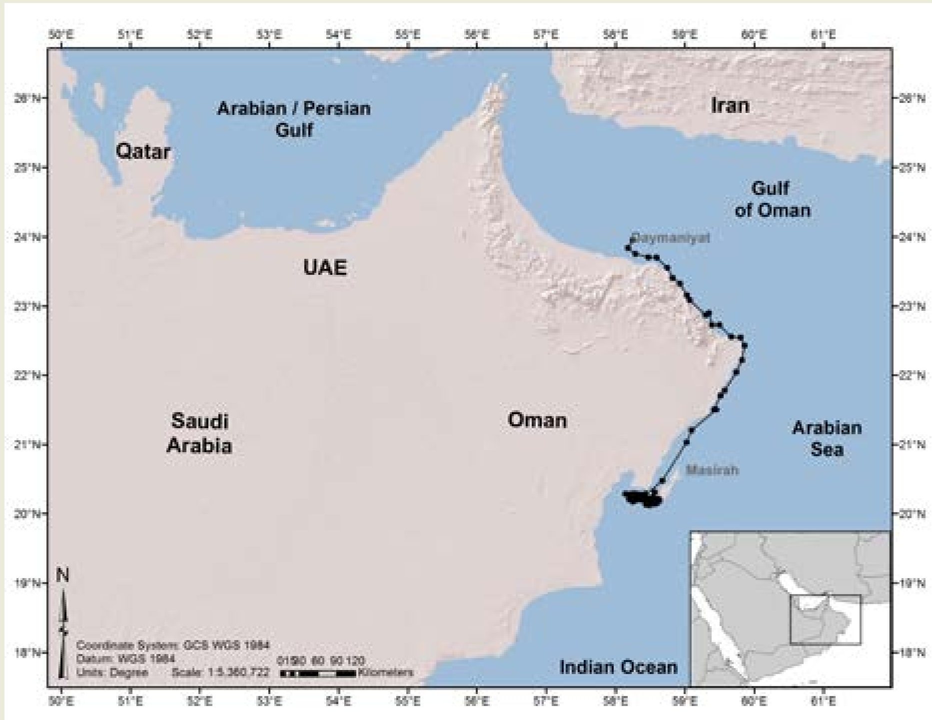
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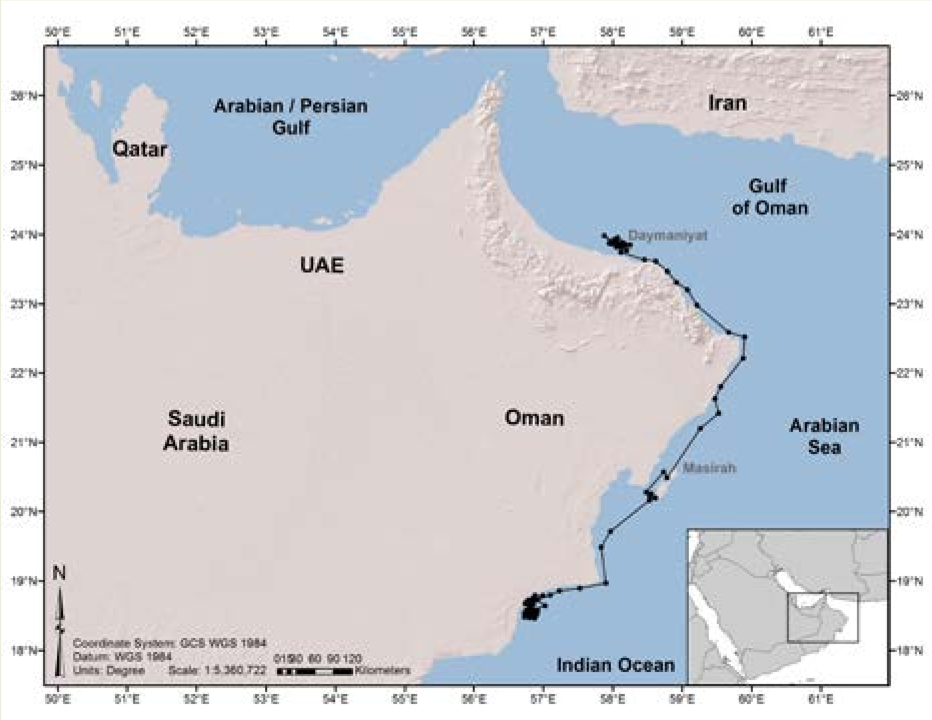
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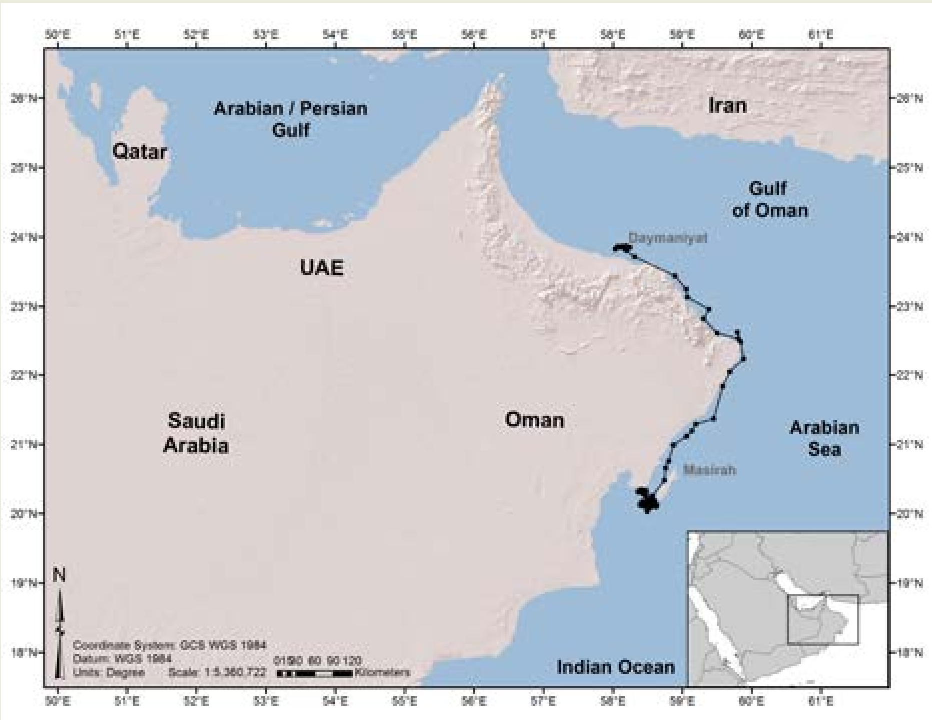
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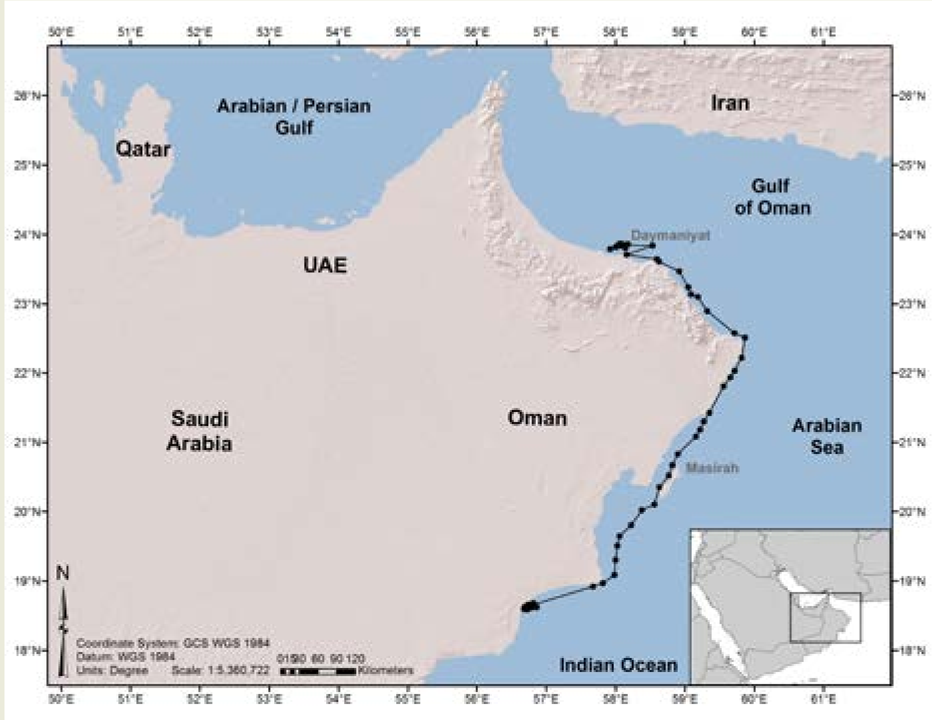
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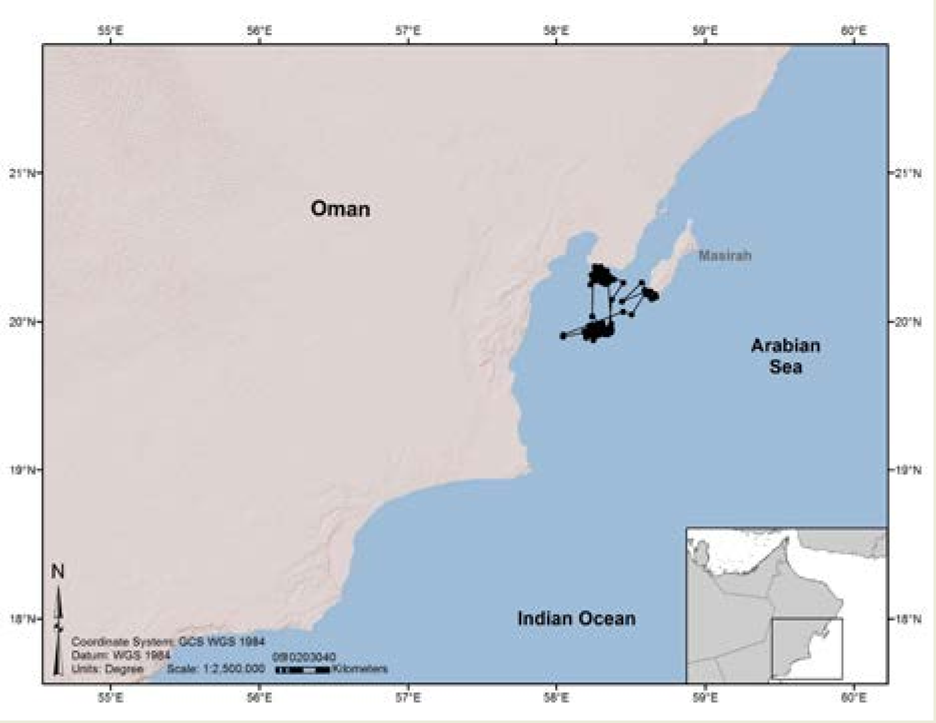
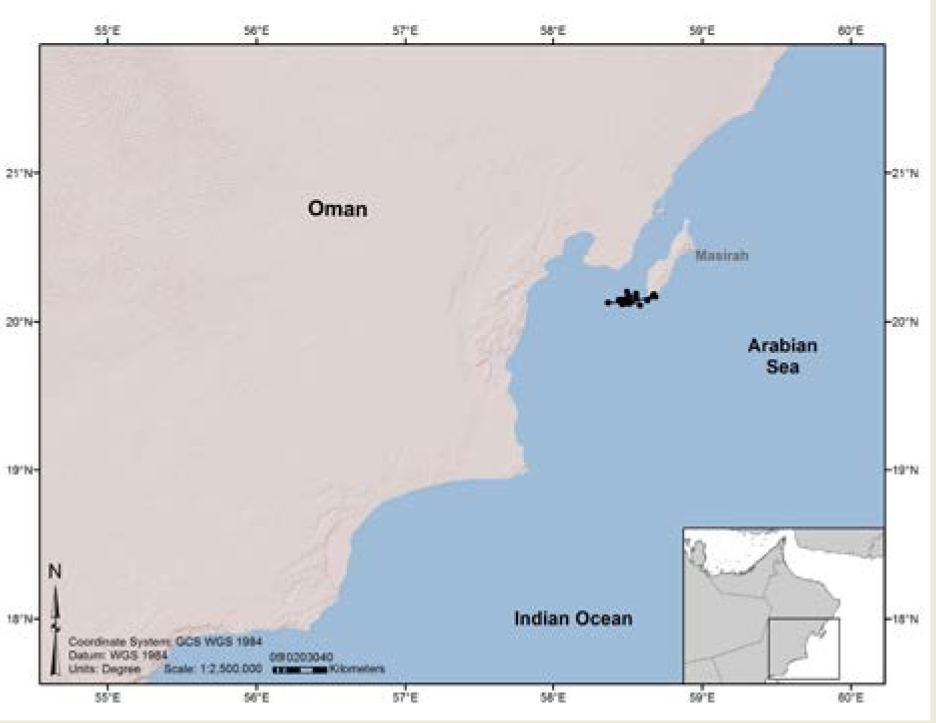
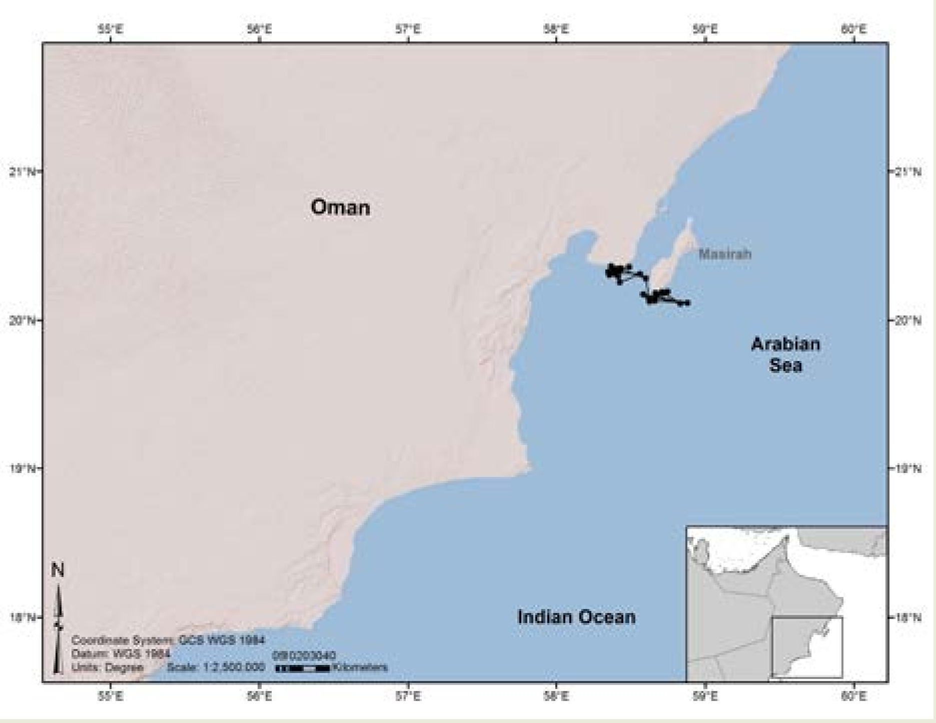
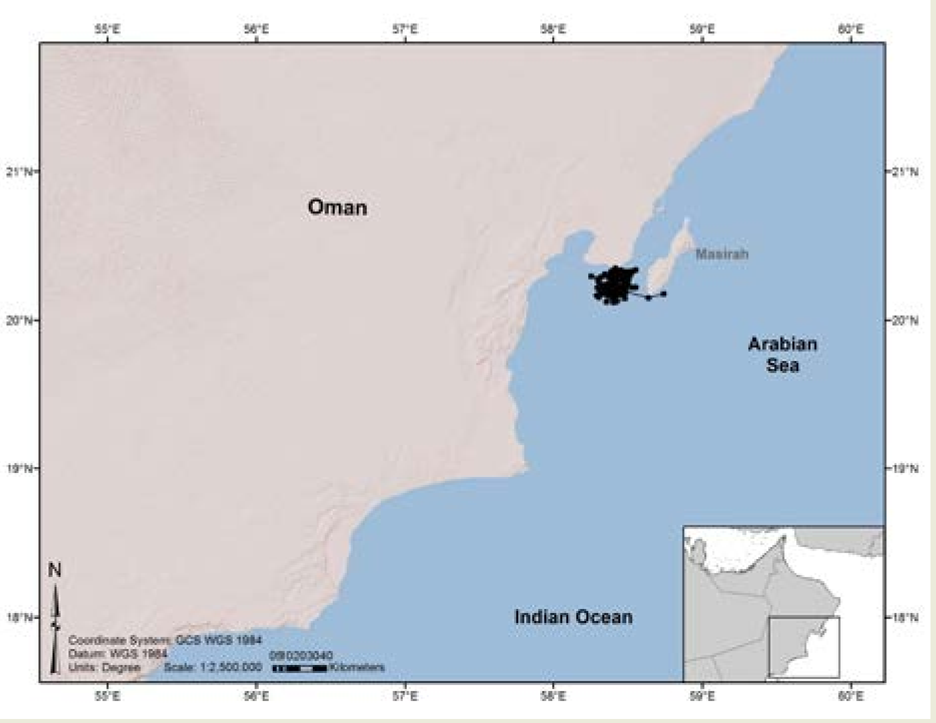
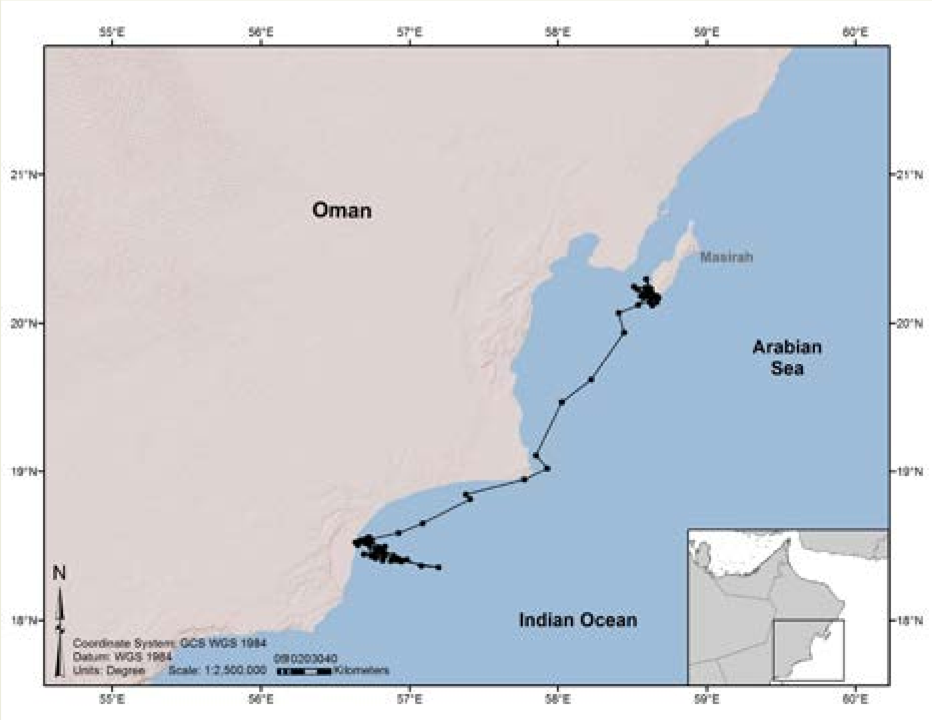
OMAN - MASIRAH ISLAND







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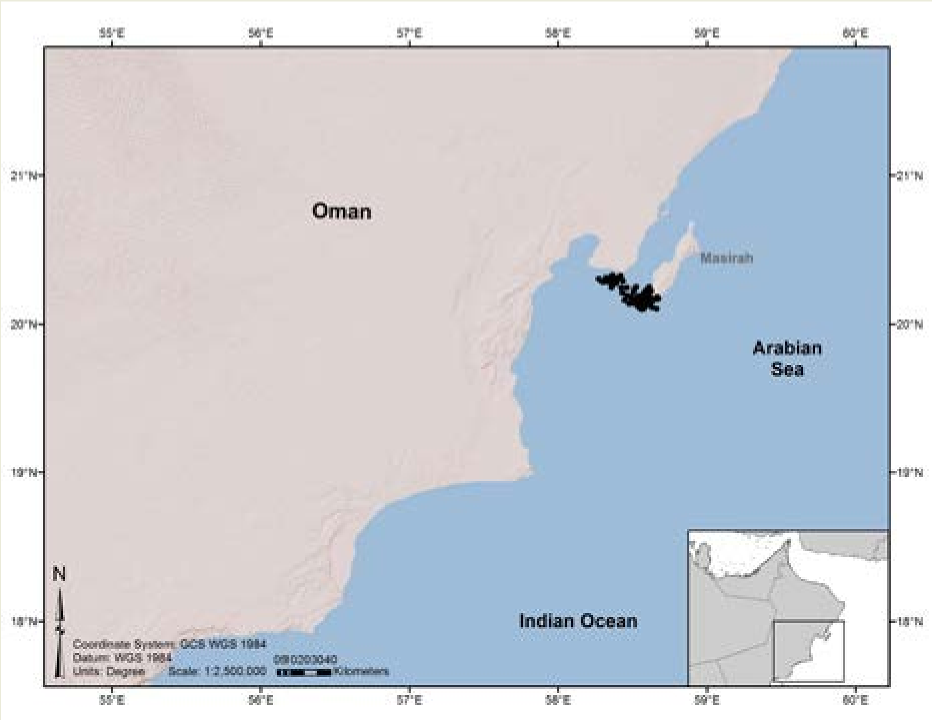
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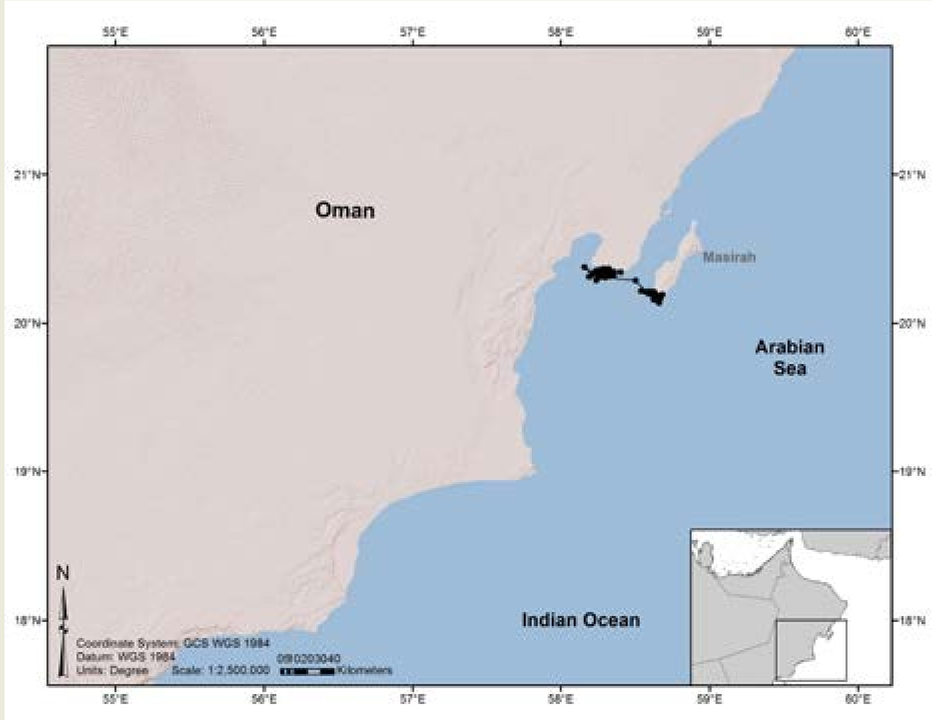
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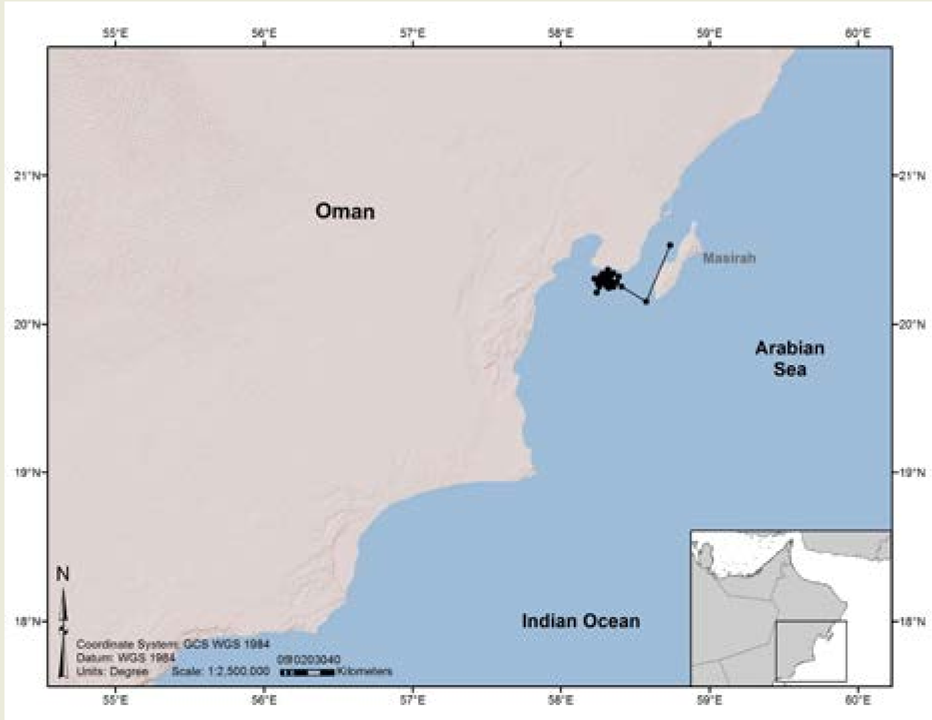
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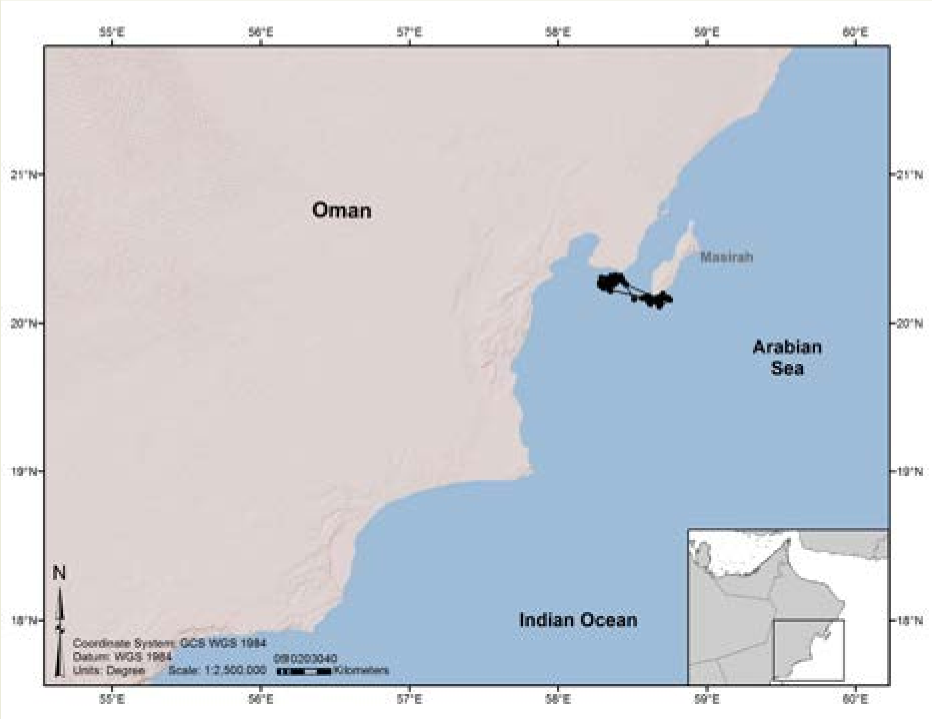
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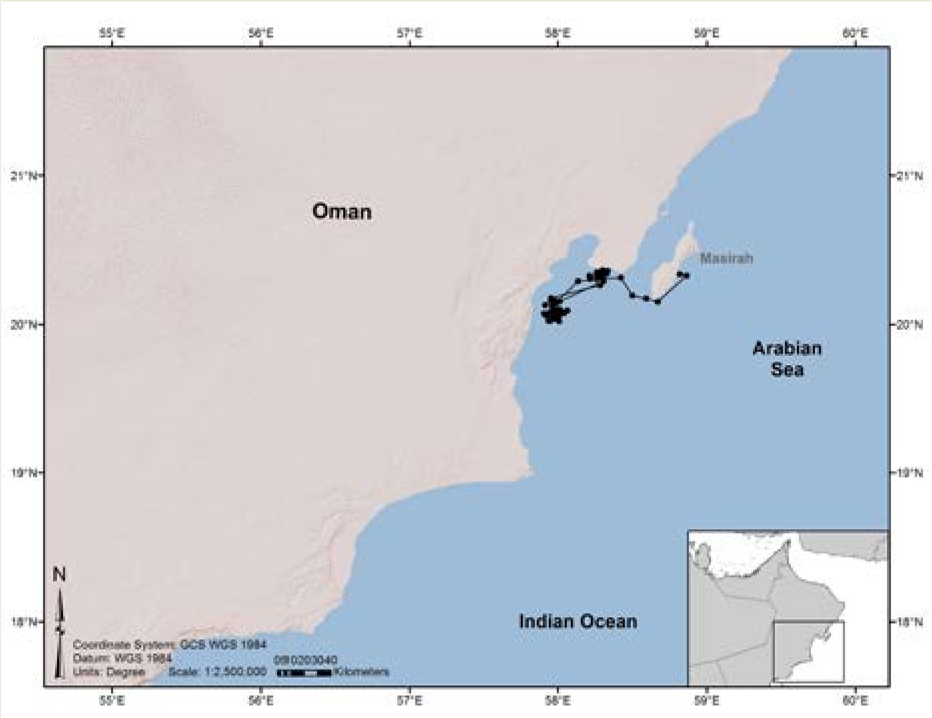
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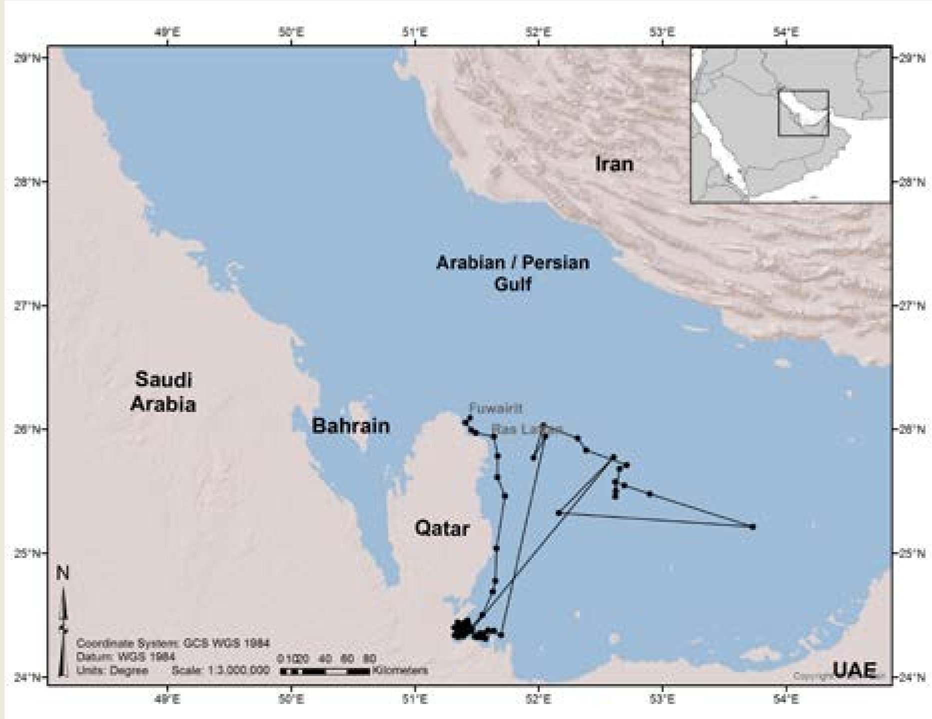
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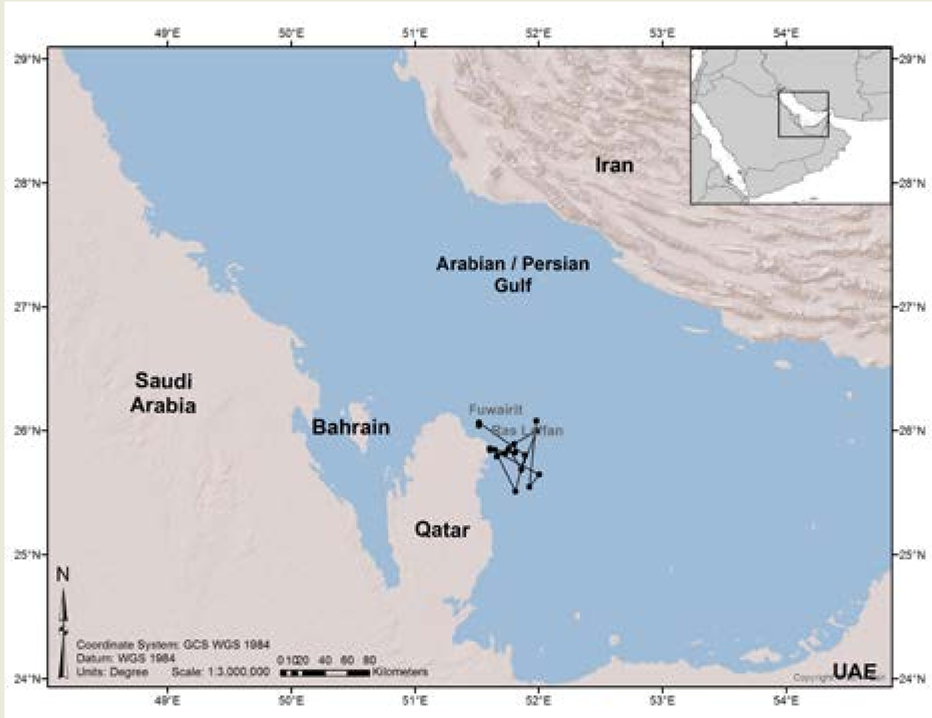
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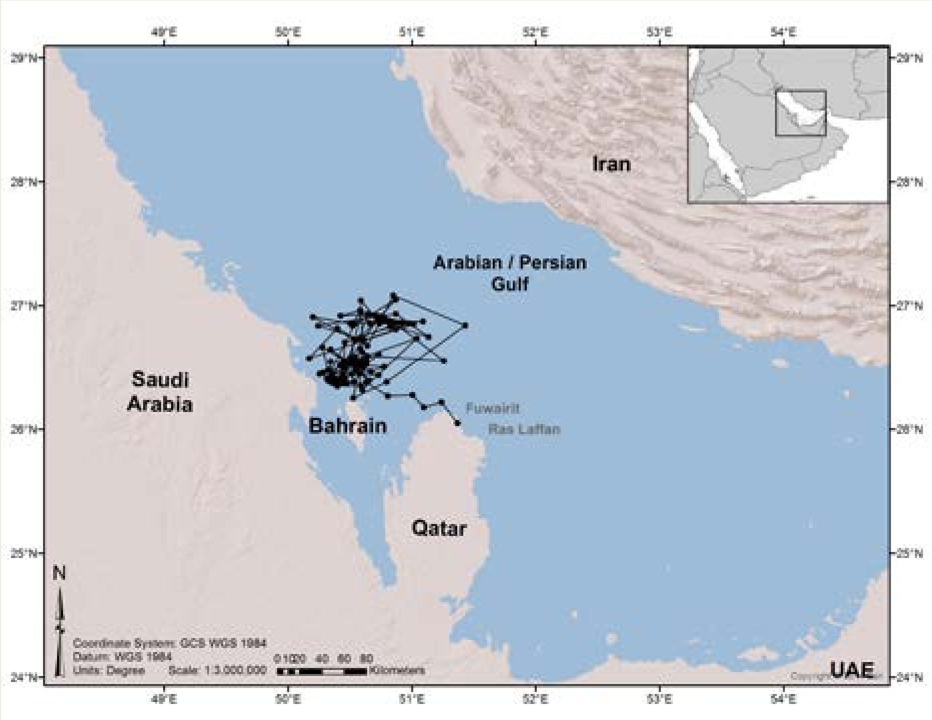
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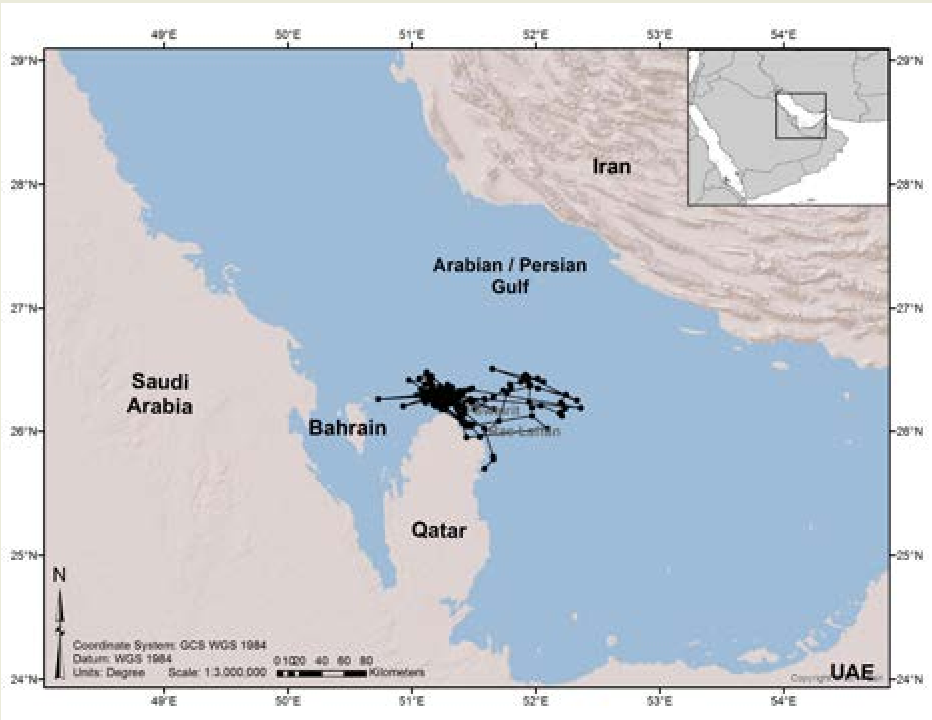
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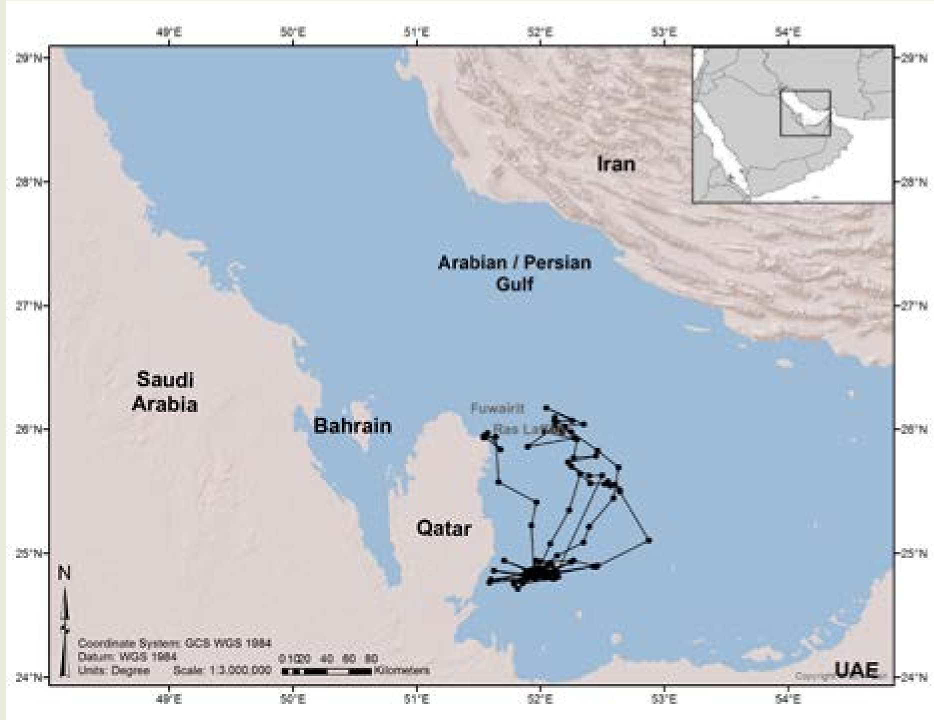
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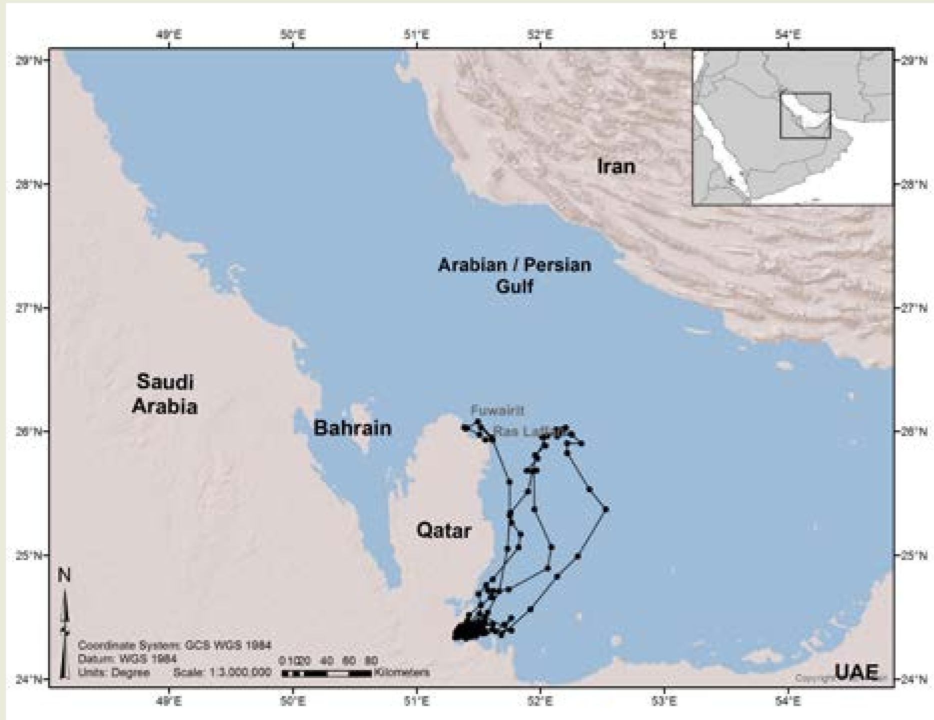
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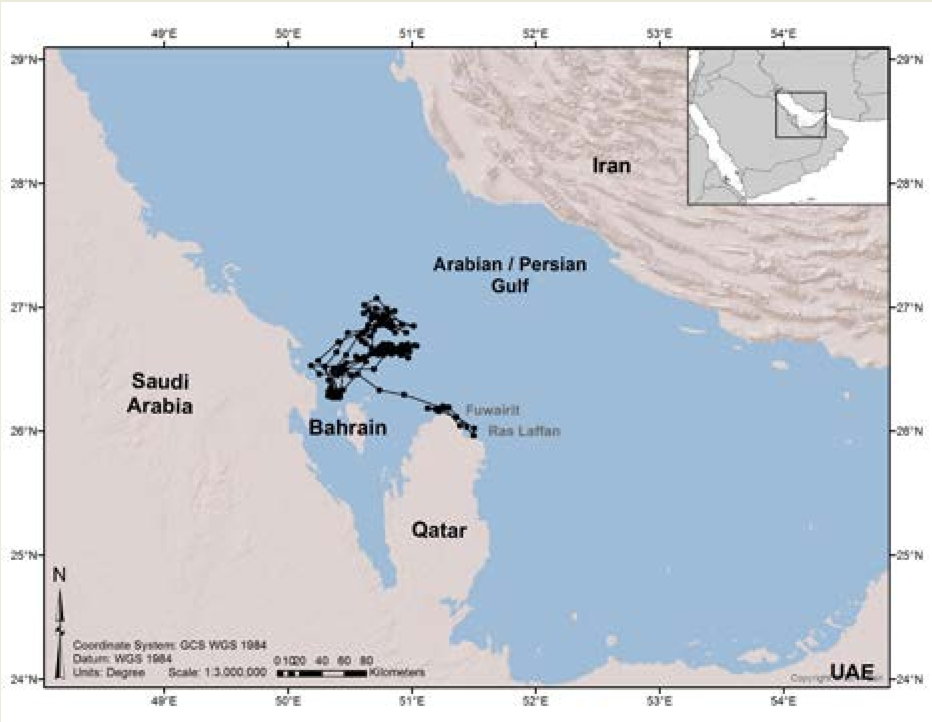
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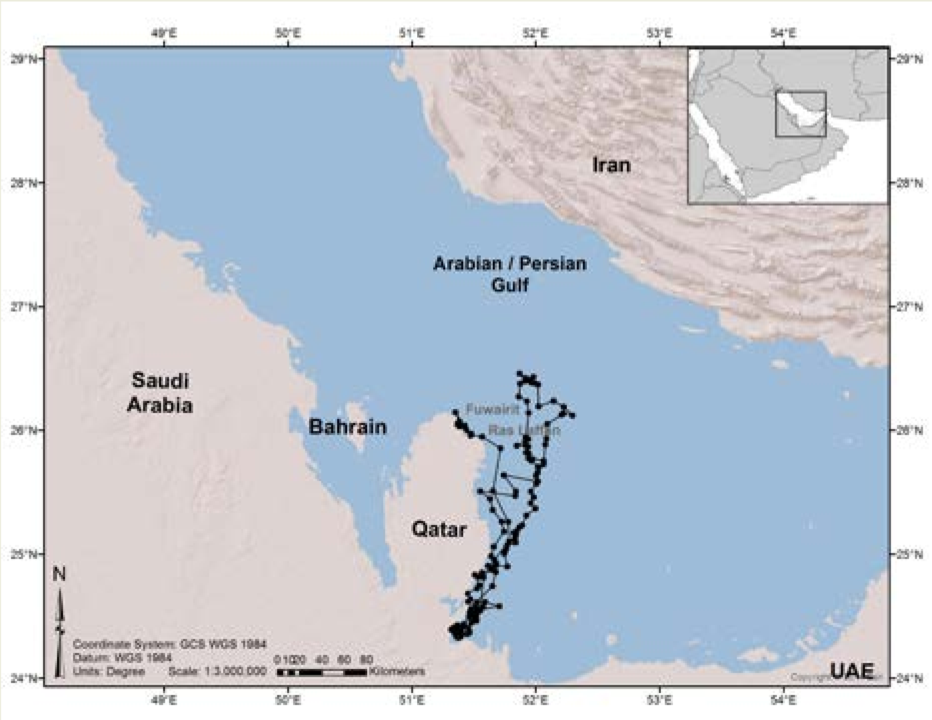
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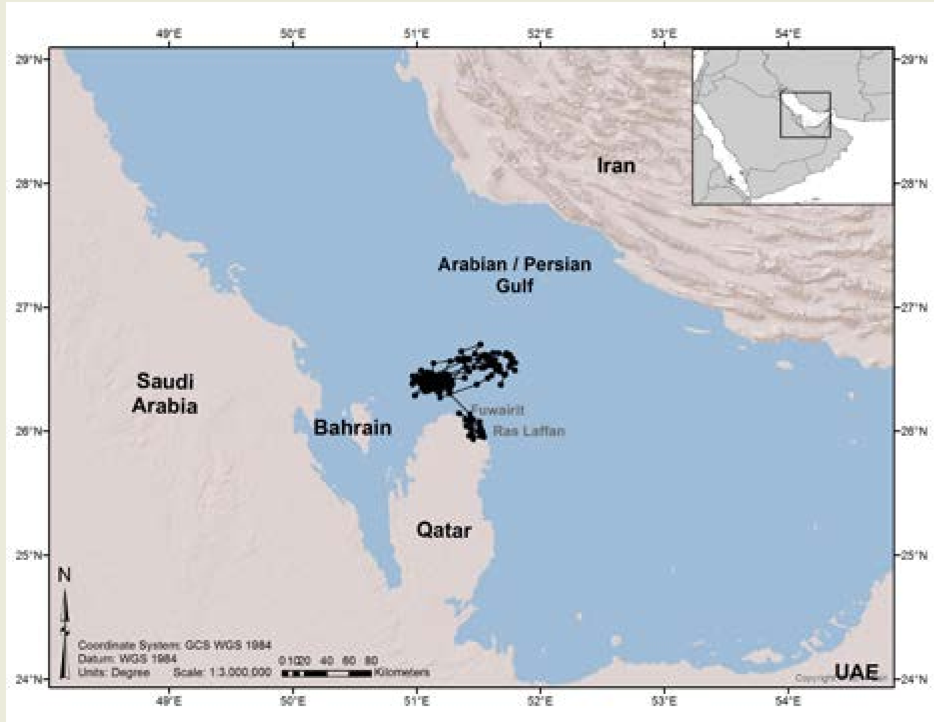
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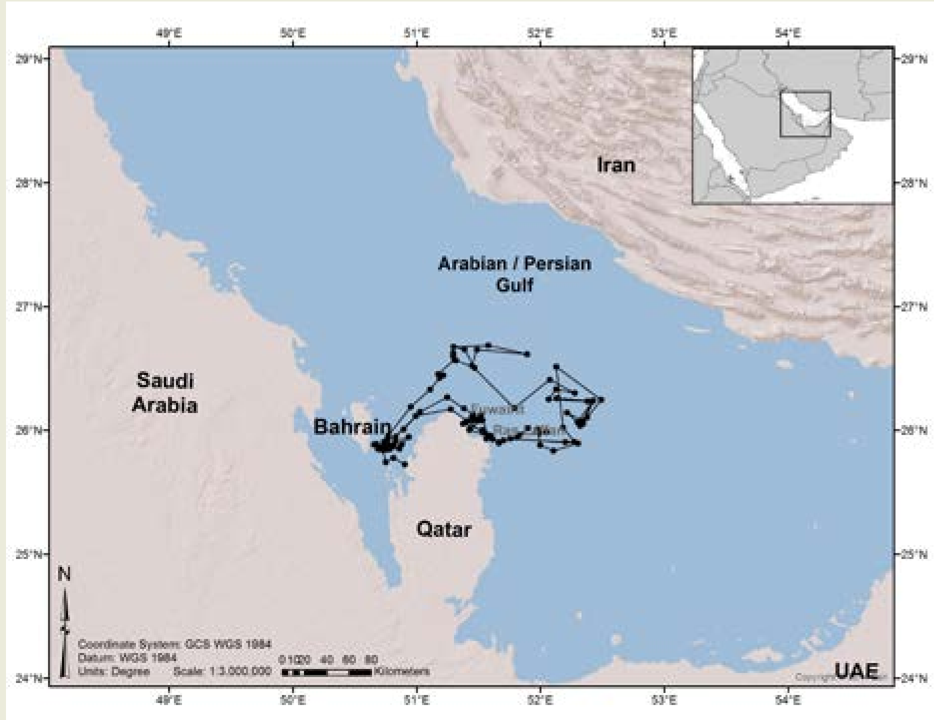
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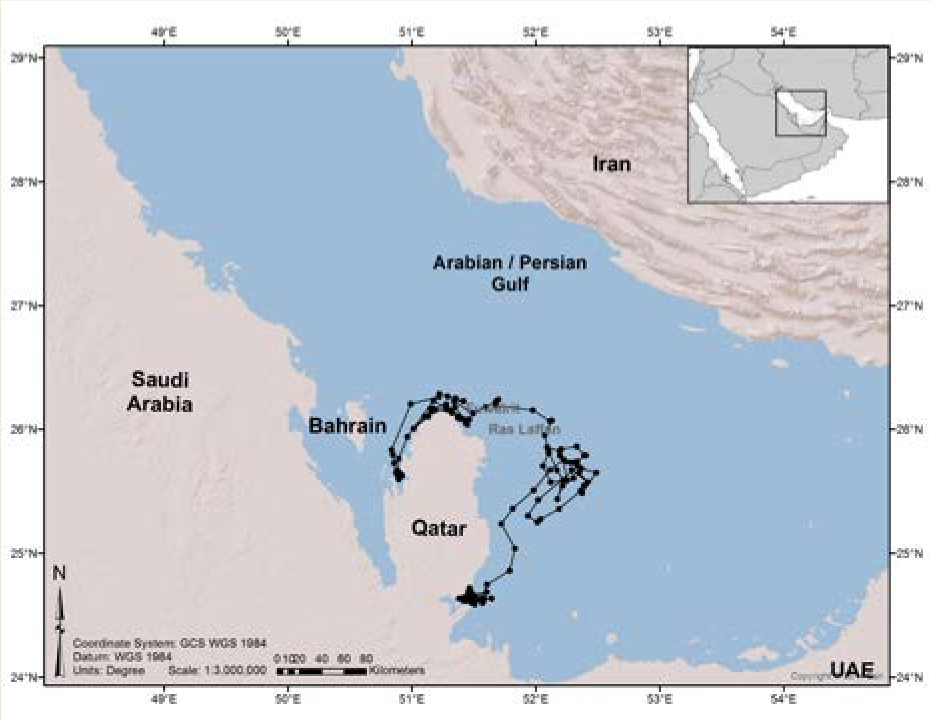

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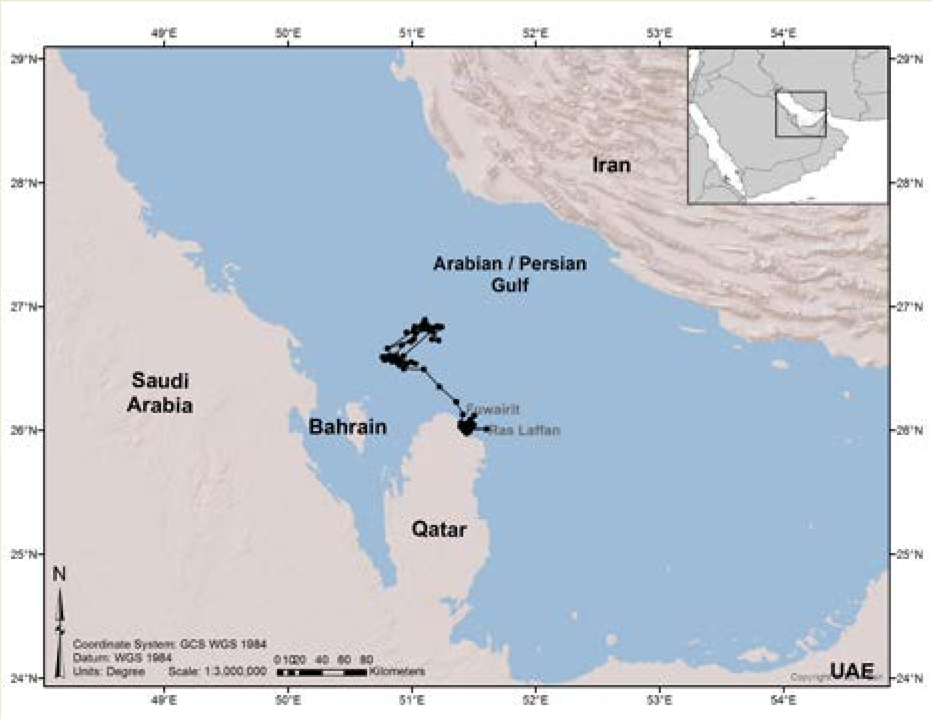

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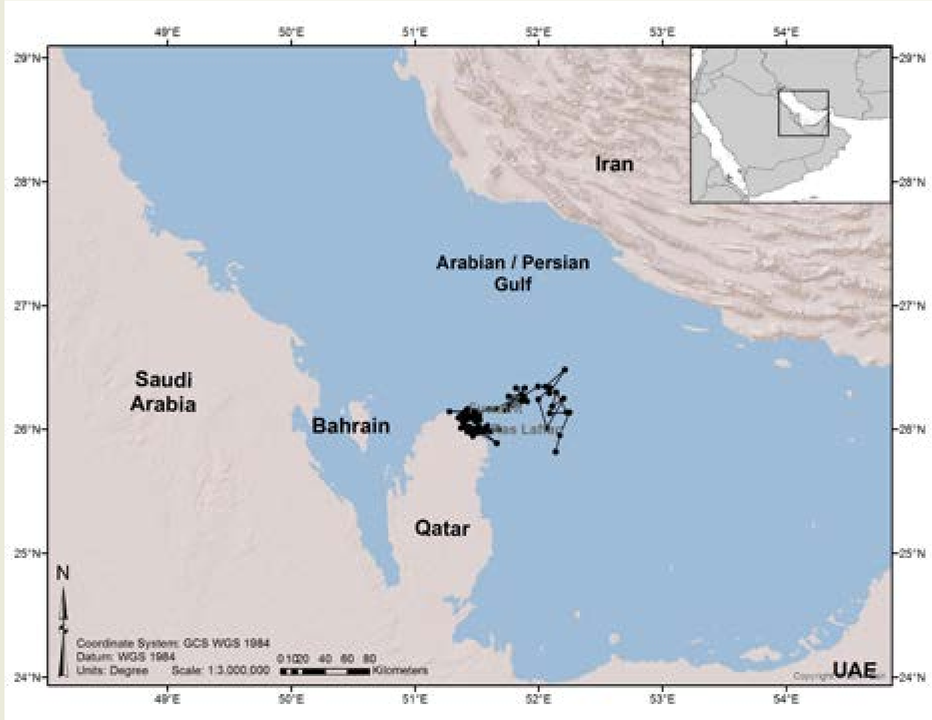

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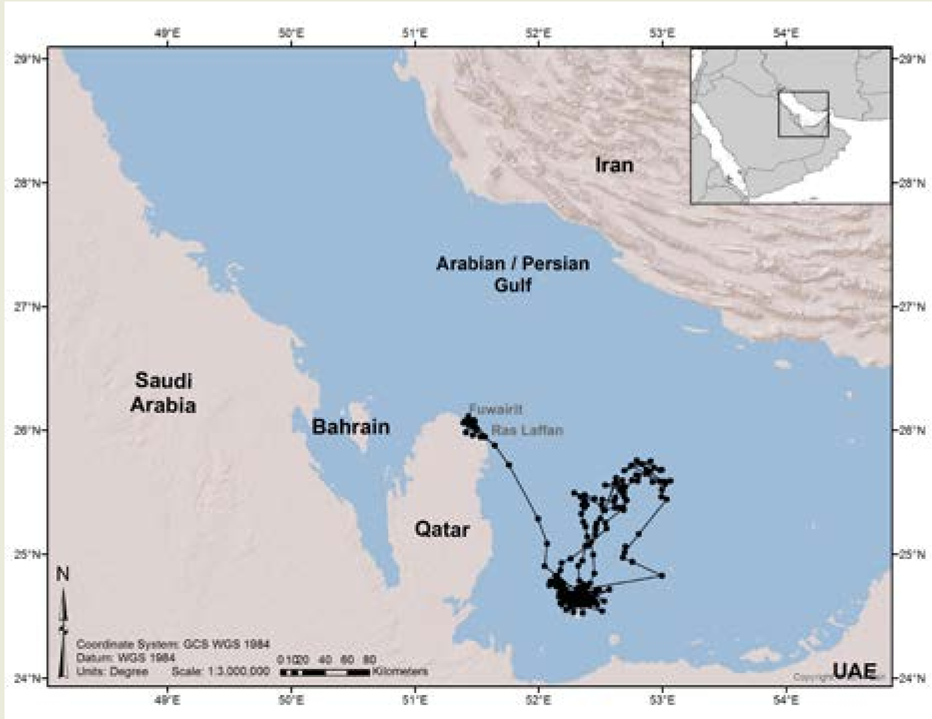

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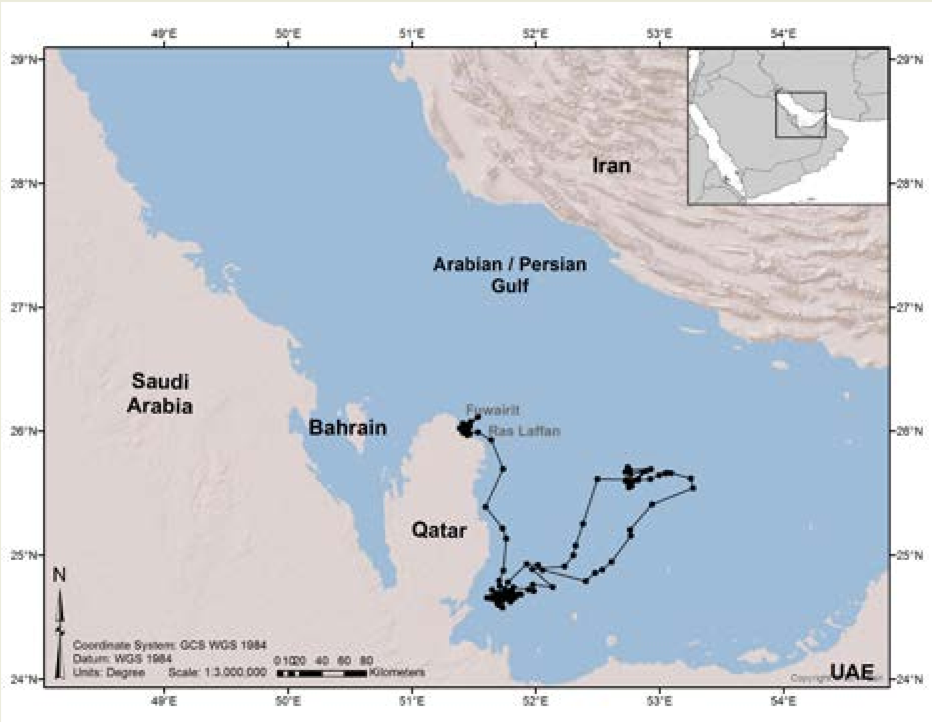
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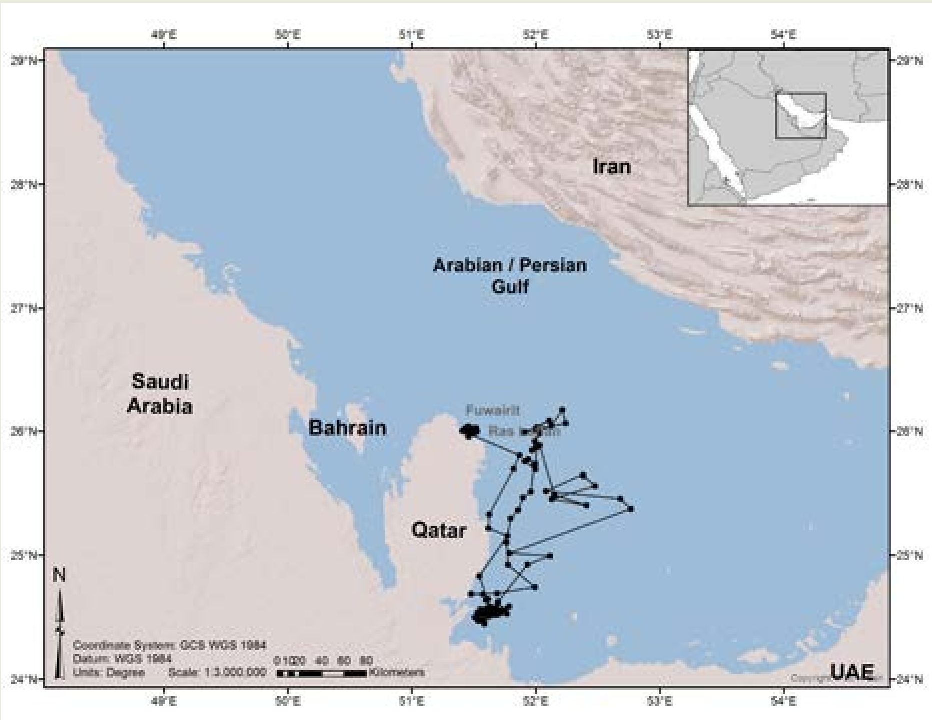
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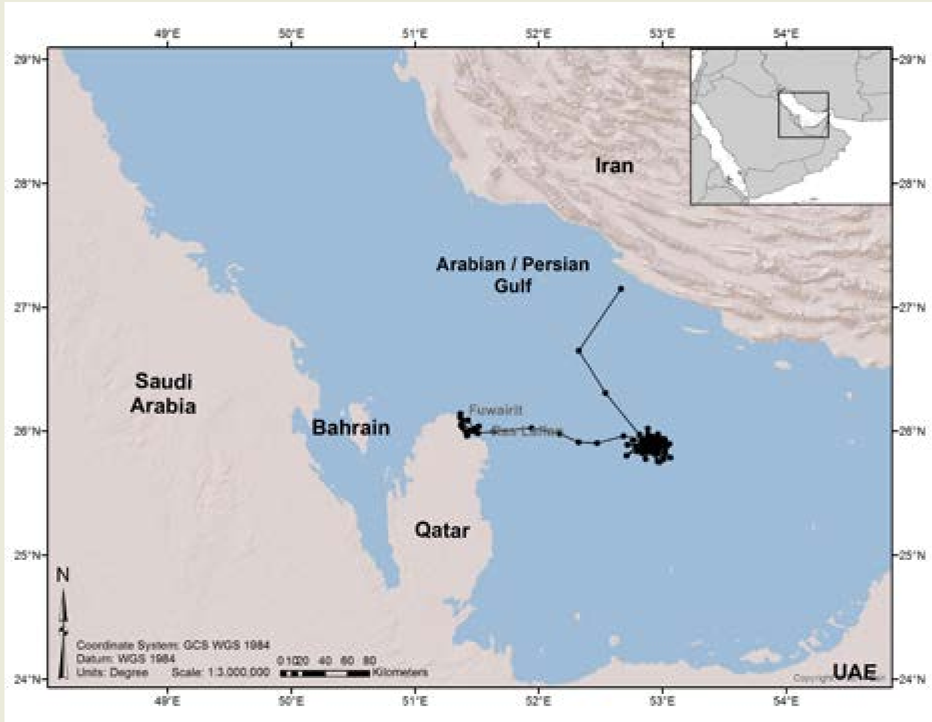
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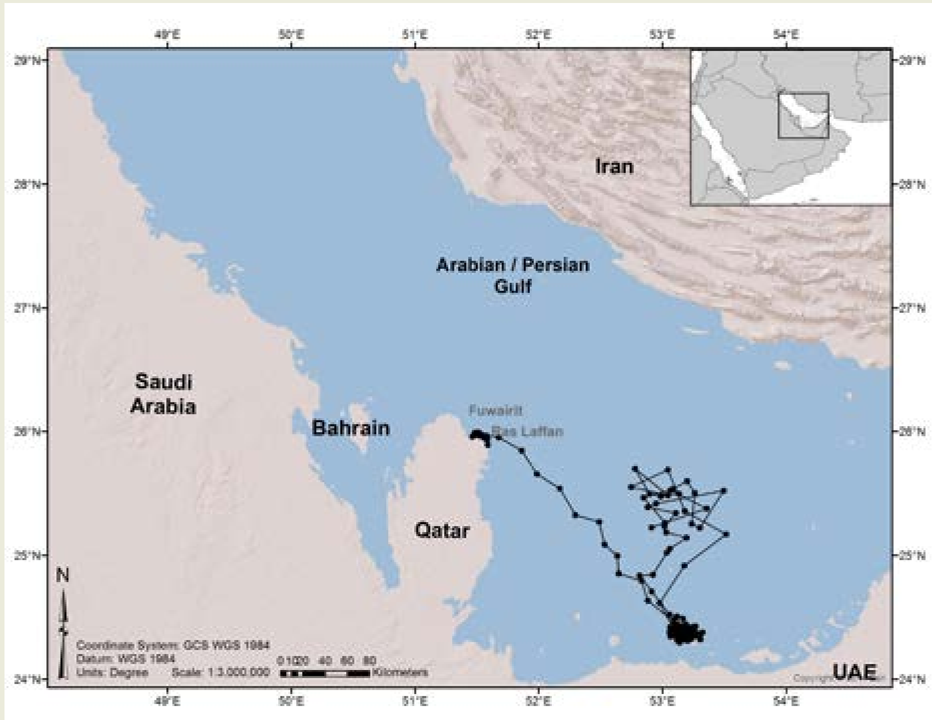
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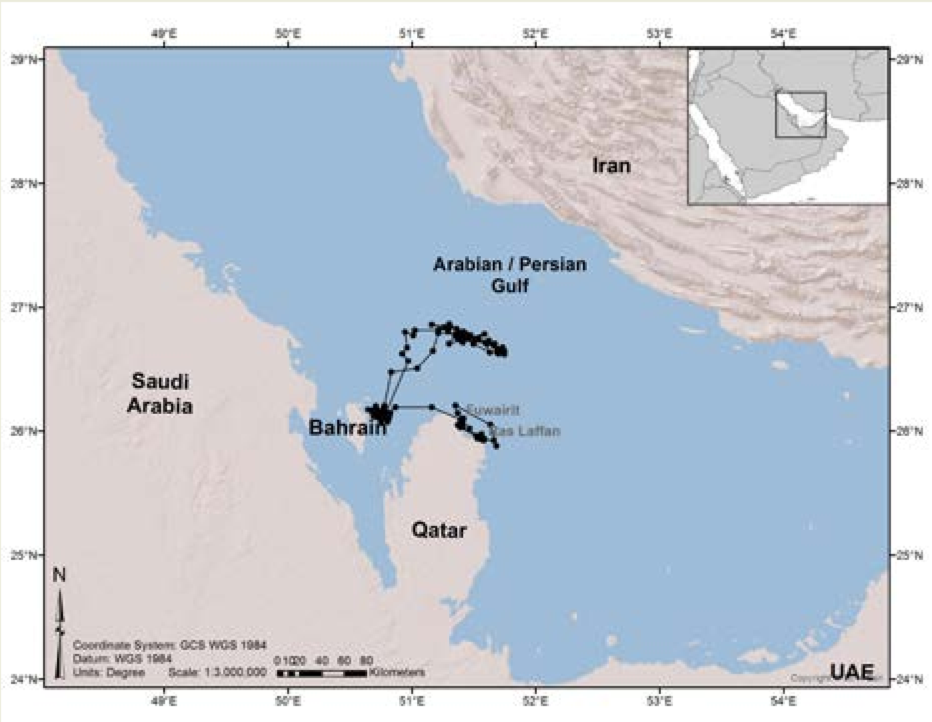
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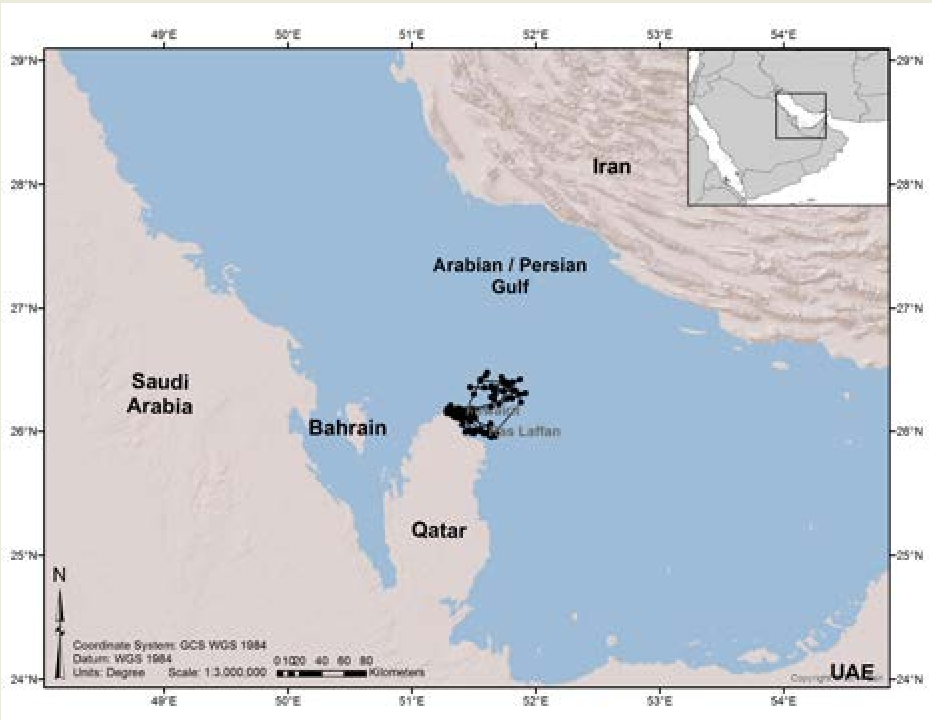
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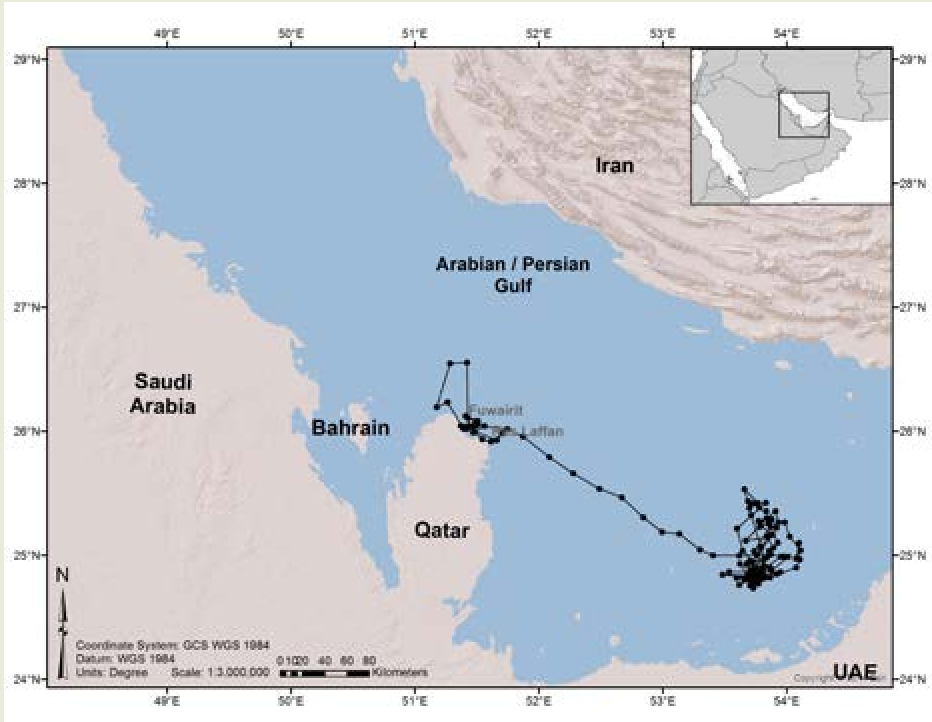
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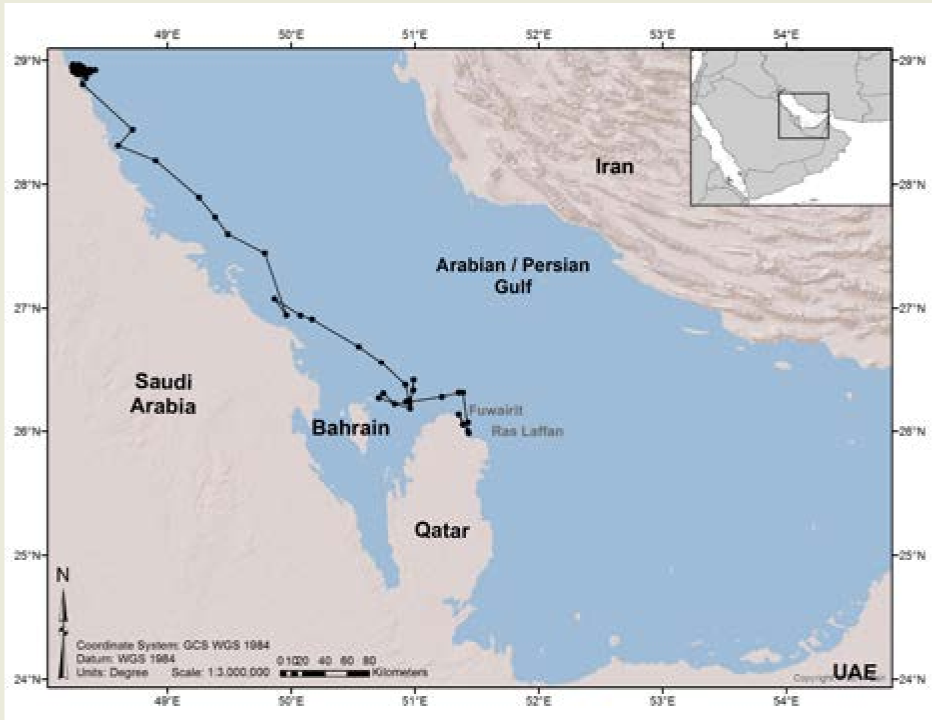
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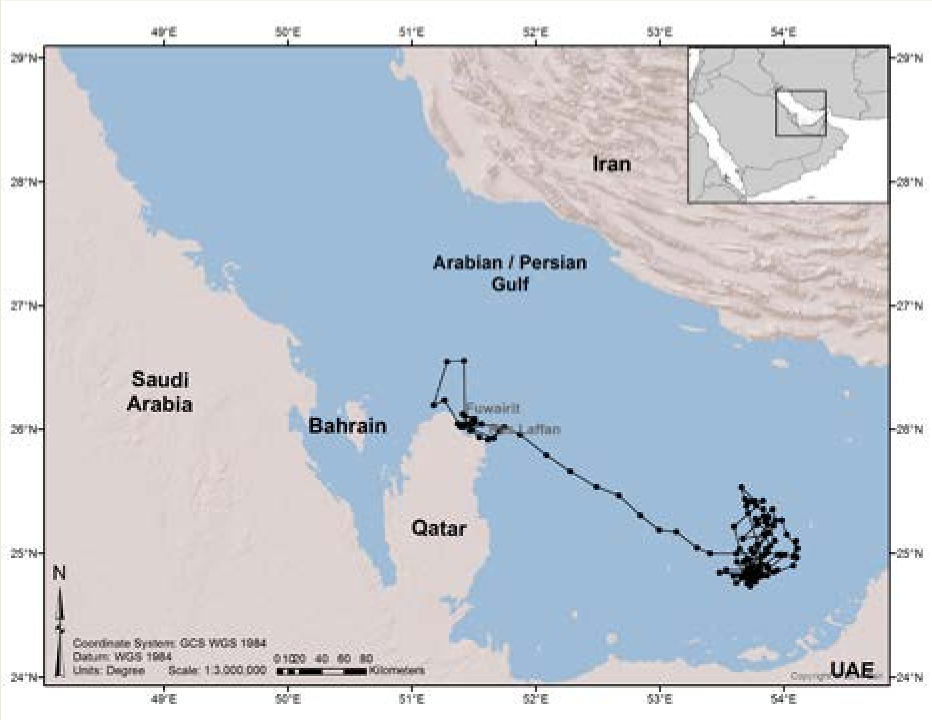
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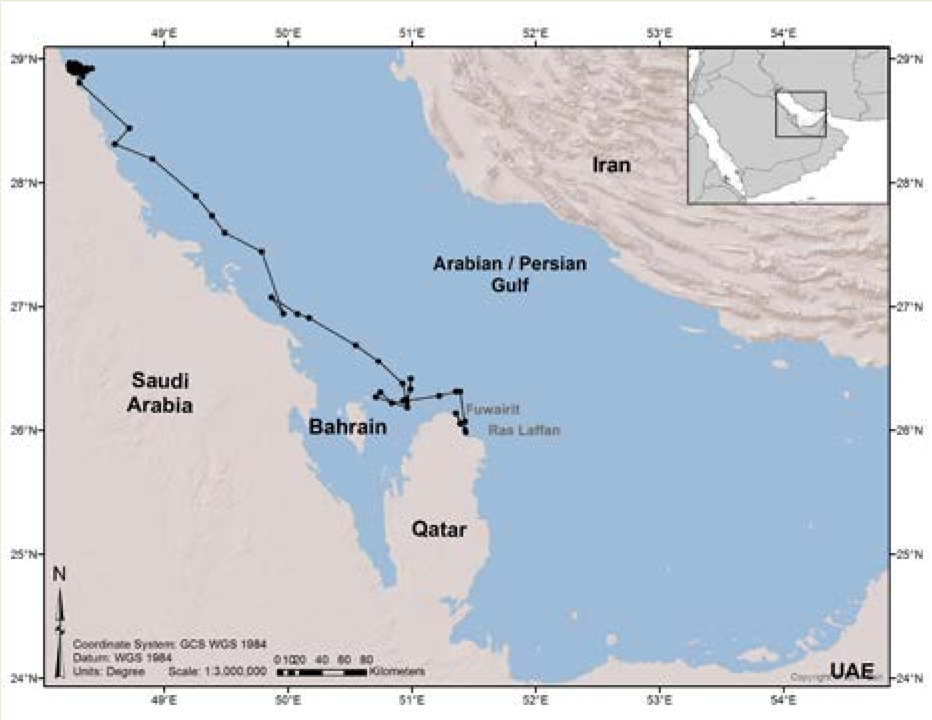
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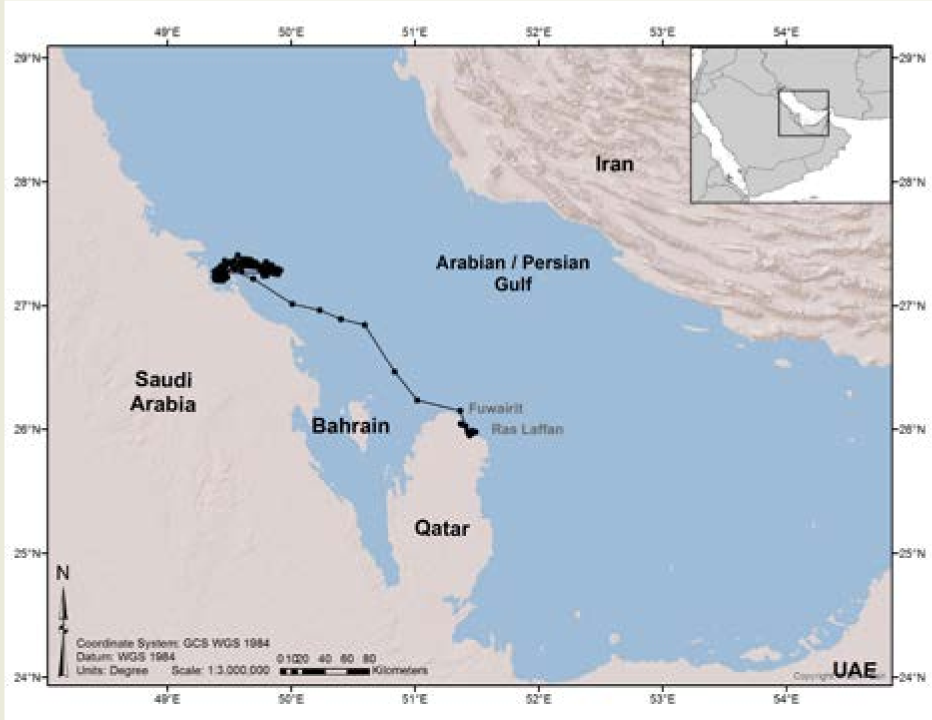
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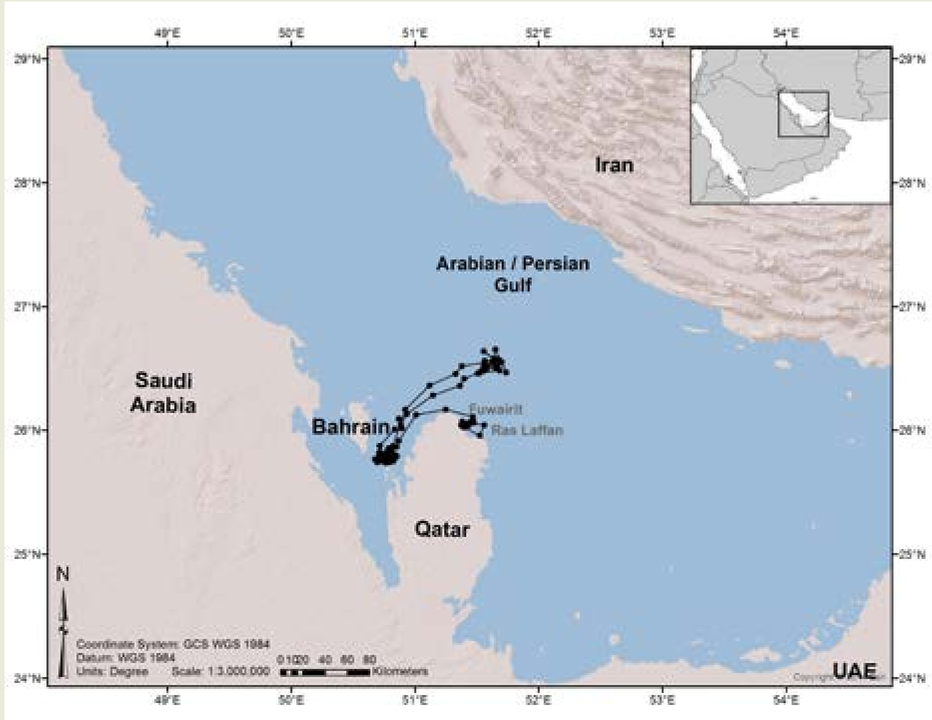
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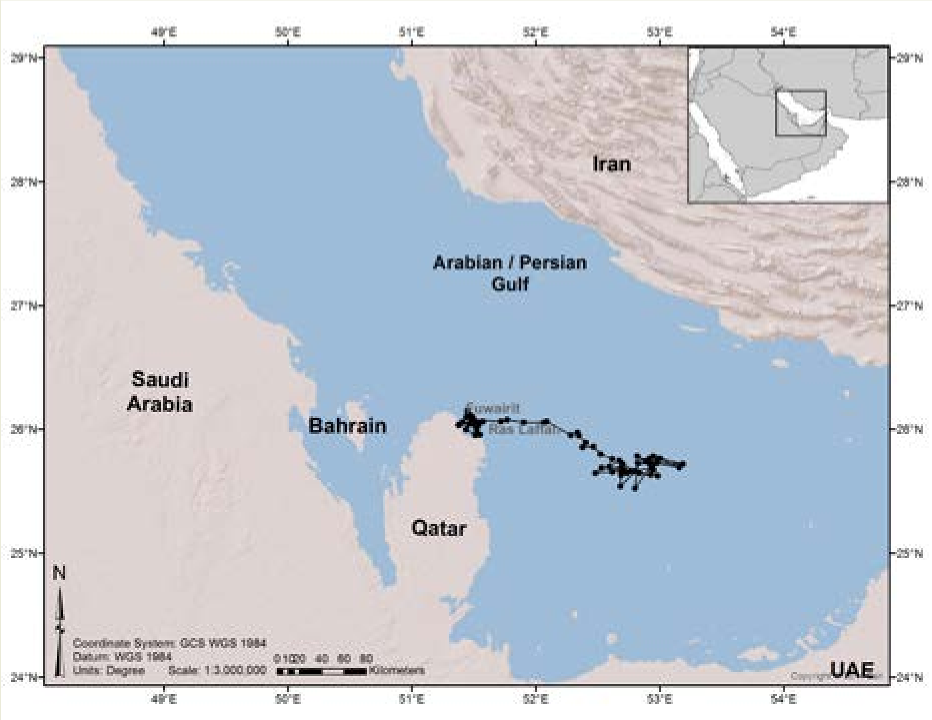
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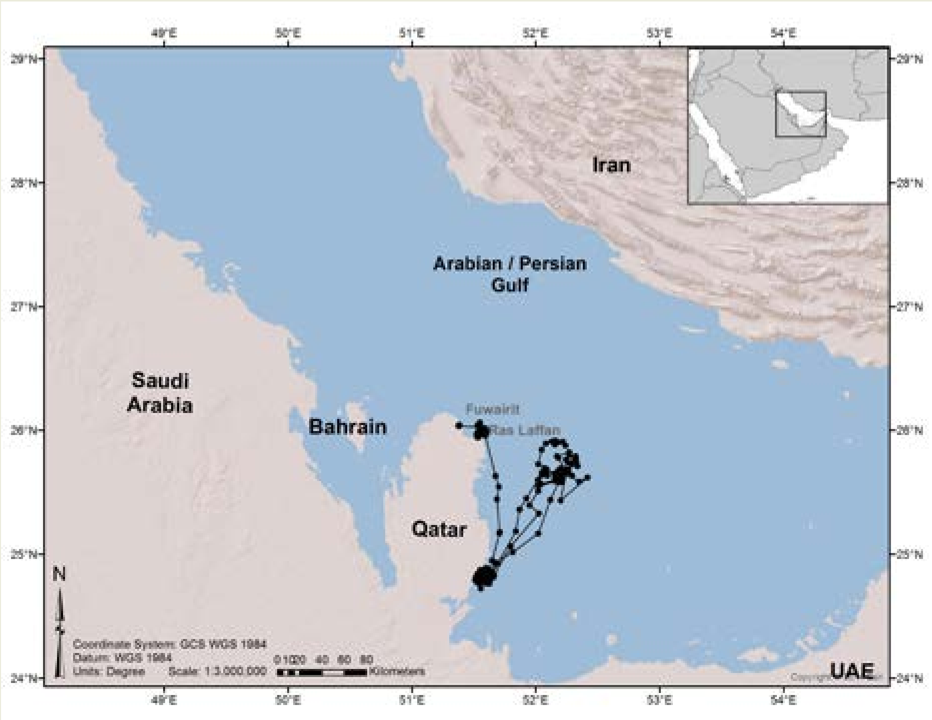
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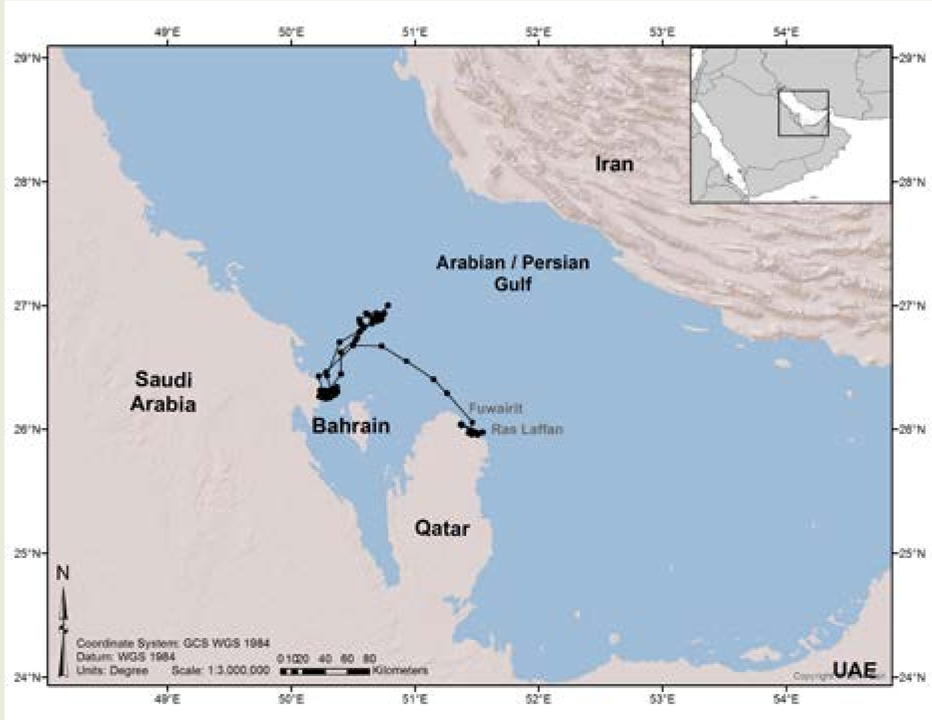
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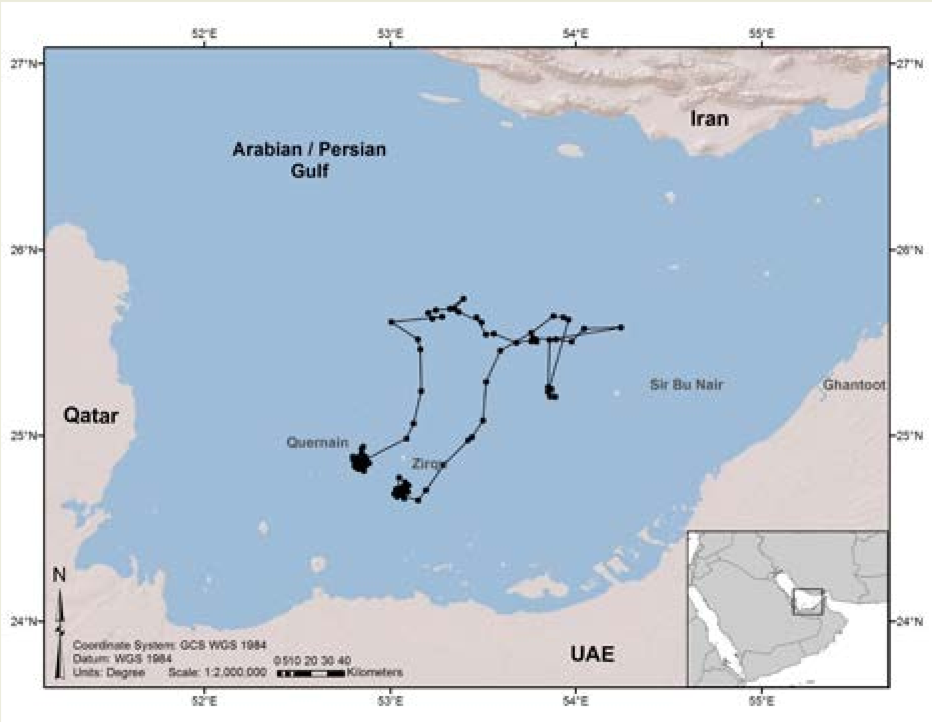
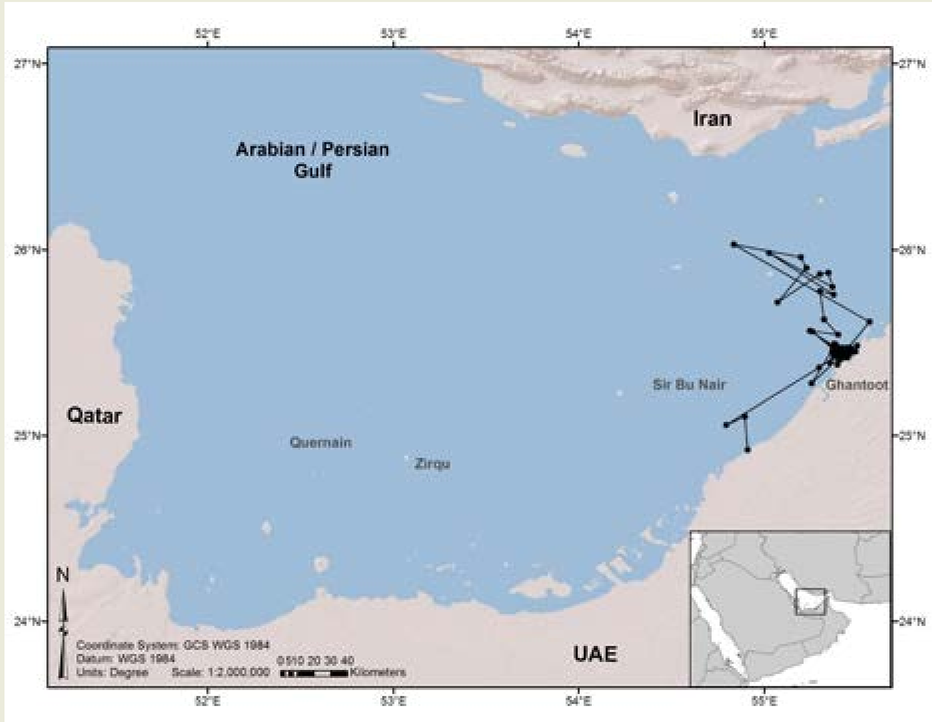
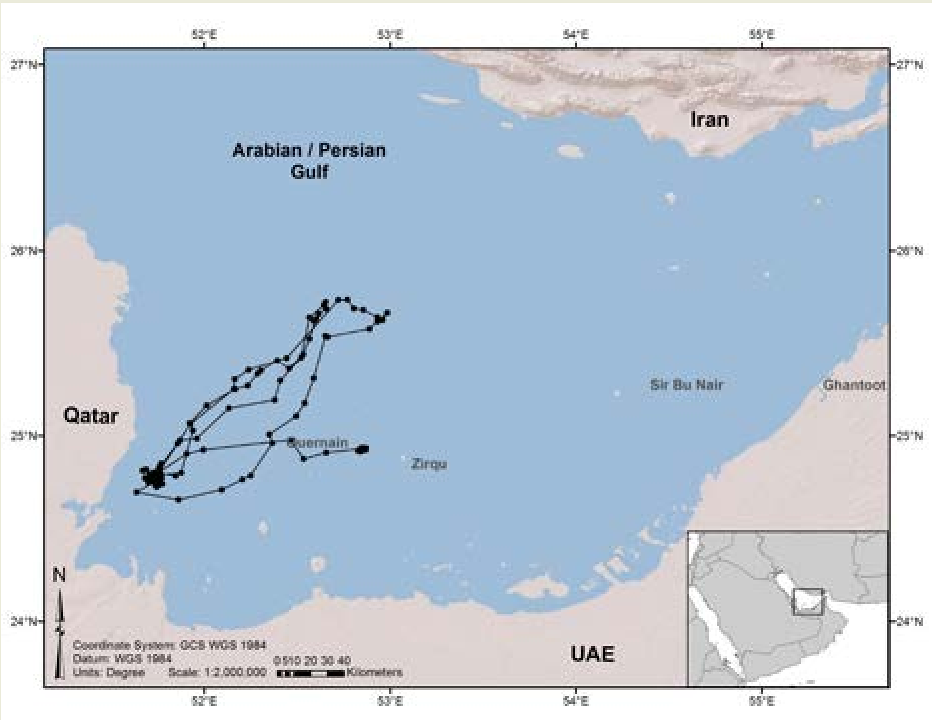
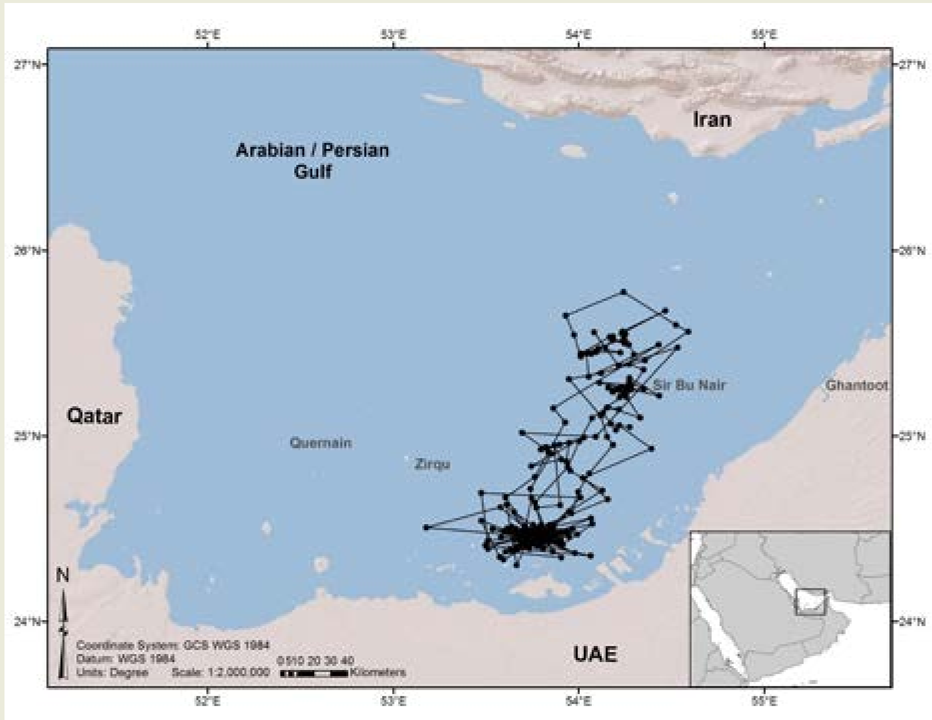
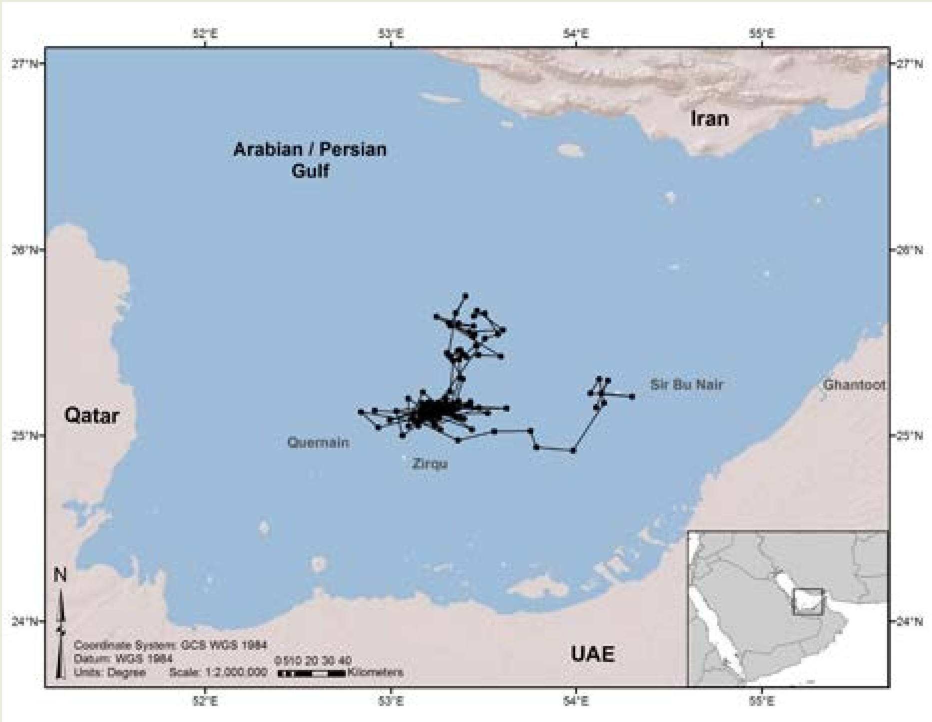
UNITED ARAB EMIRATES











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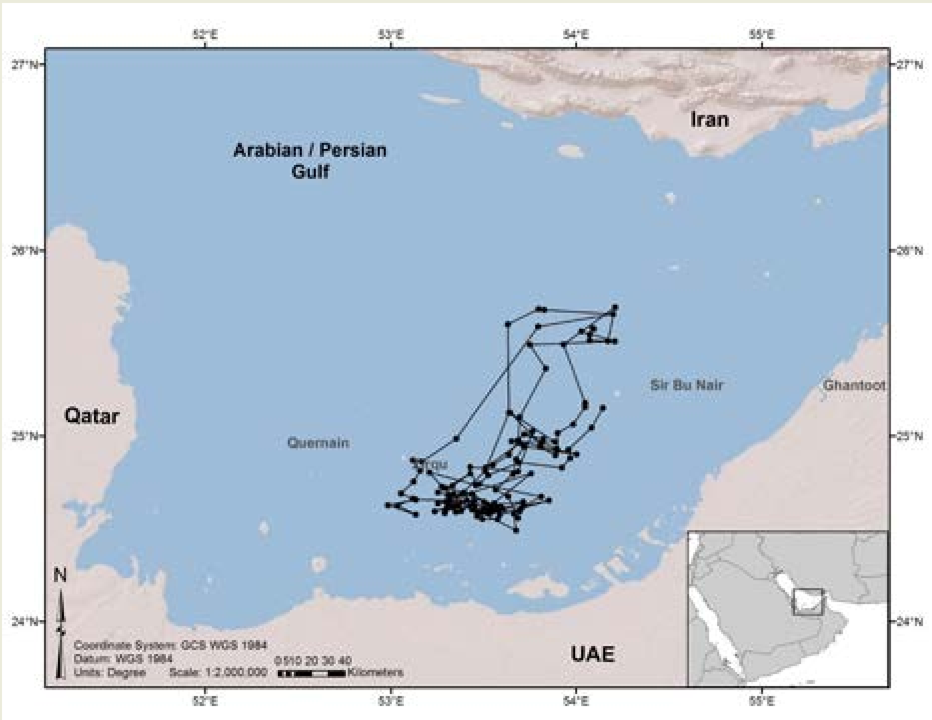

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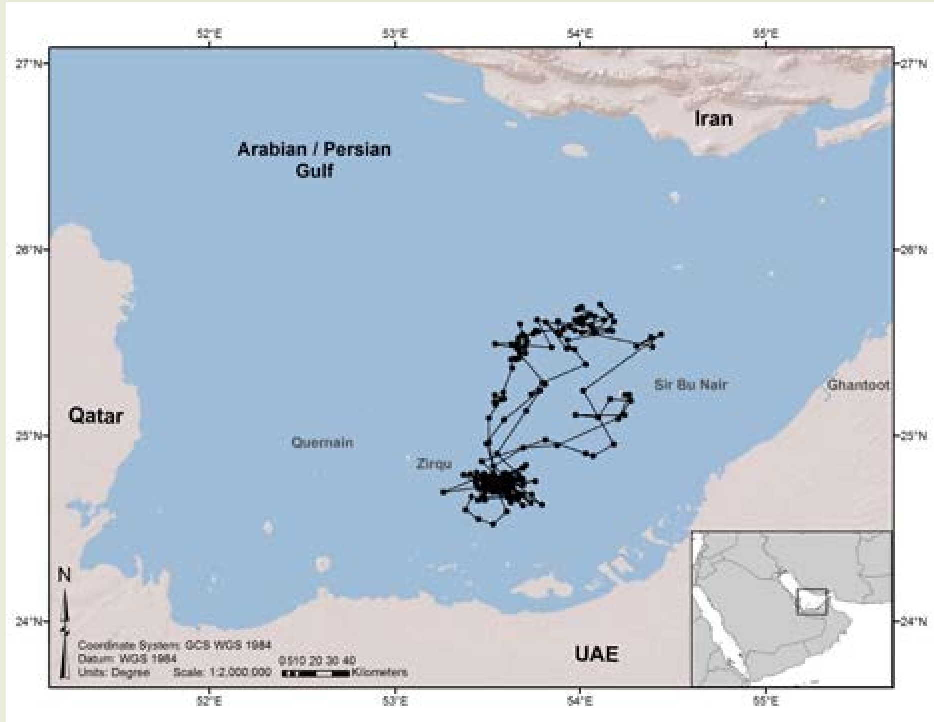

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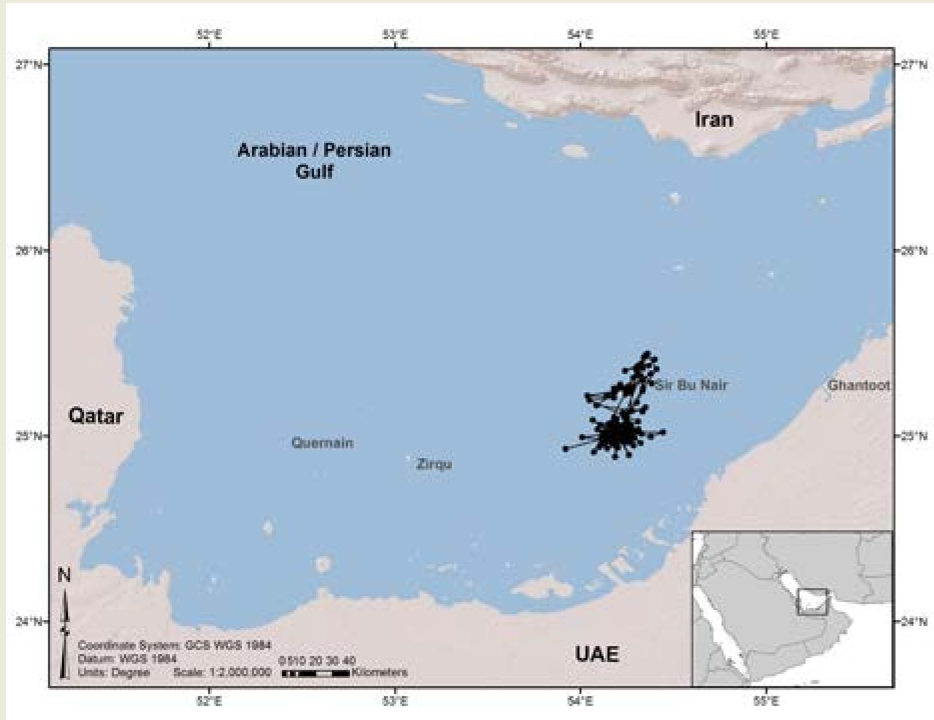

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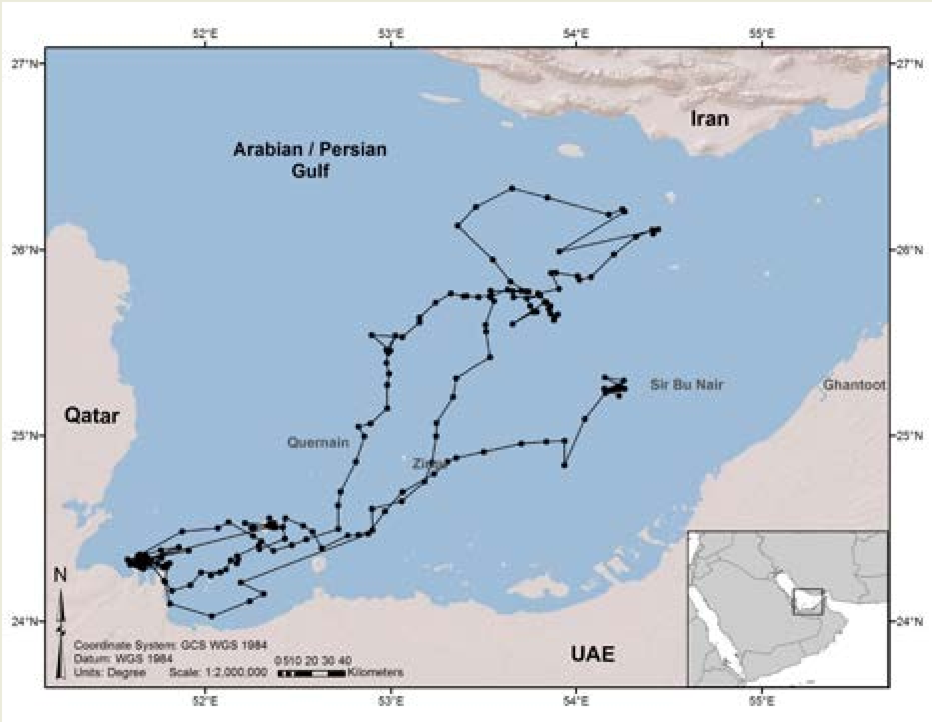
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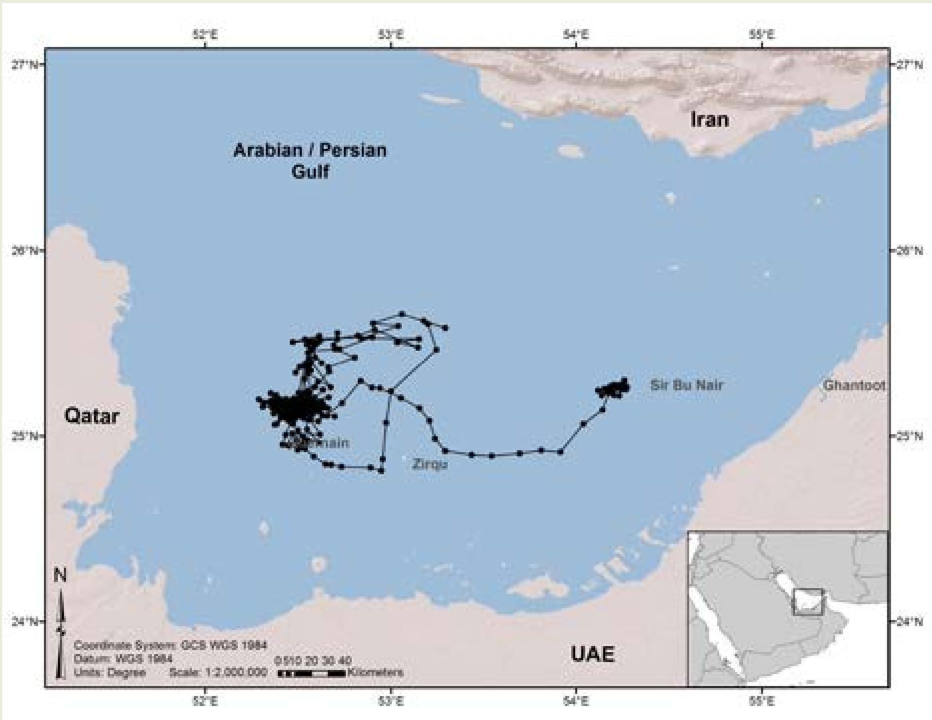
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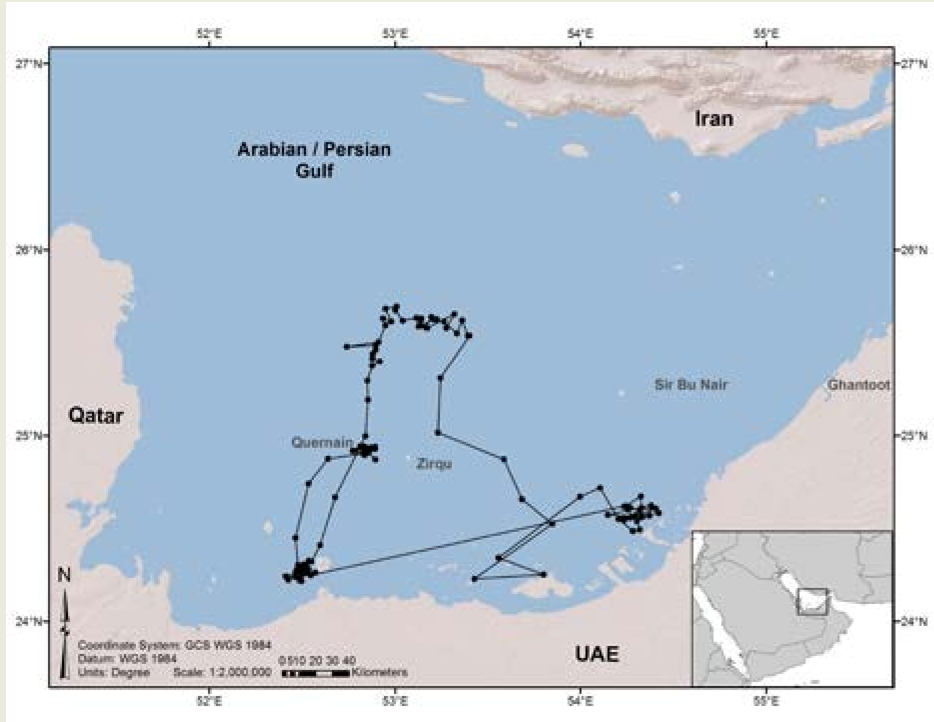
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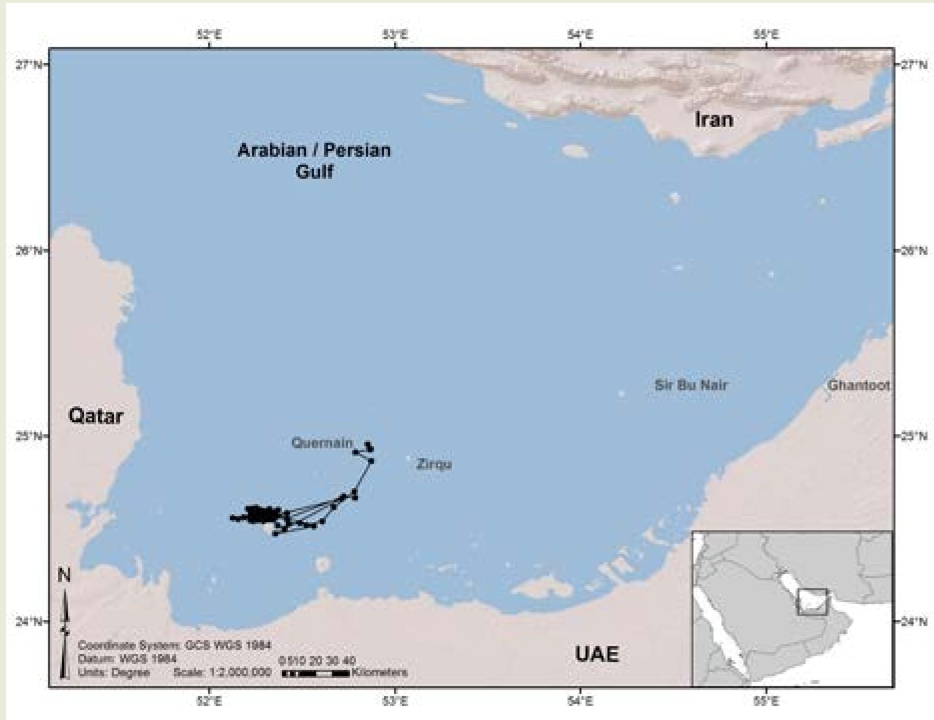
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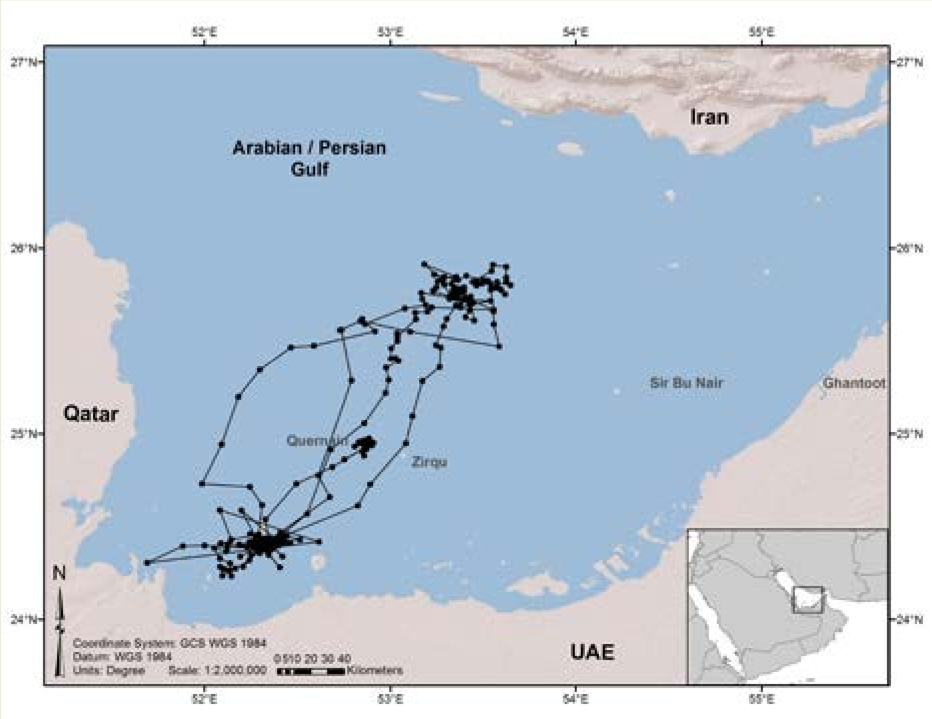
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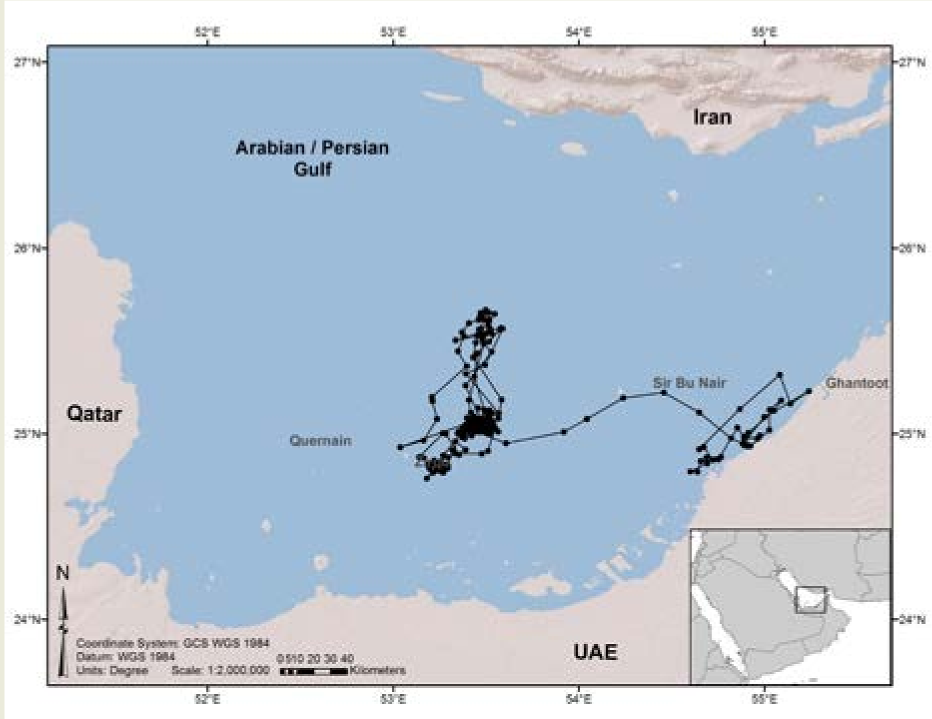
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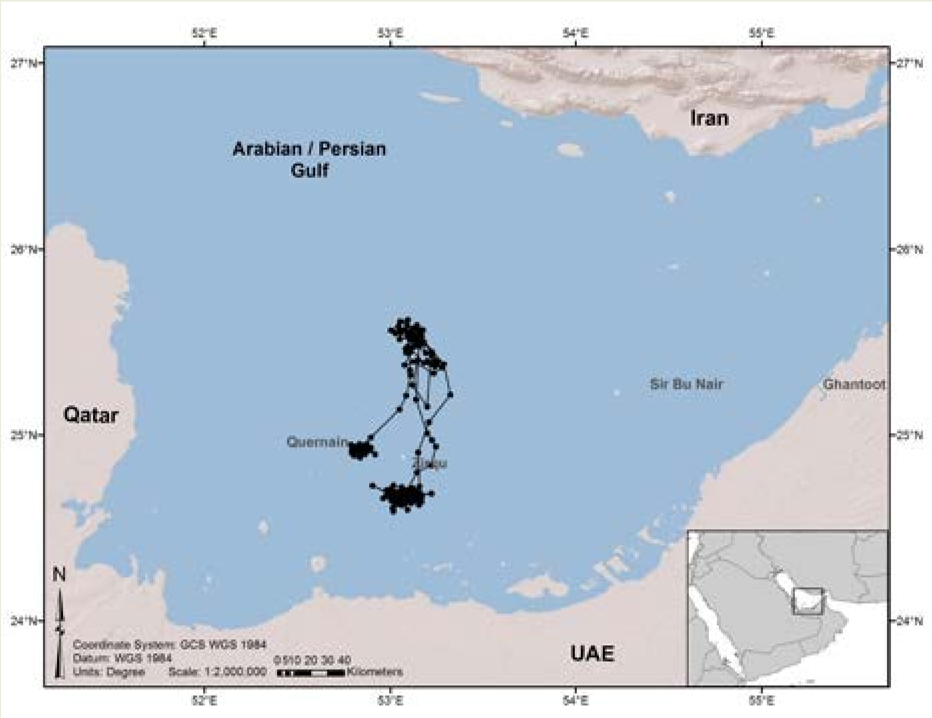
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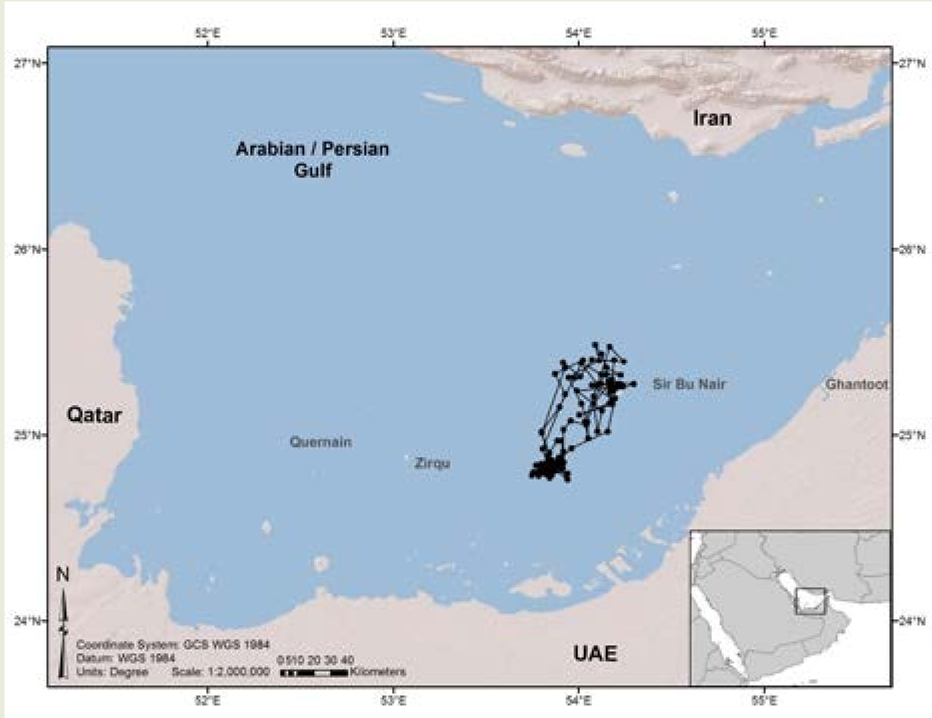
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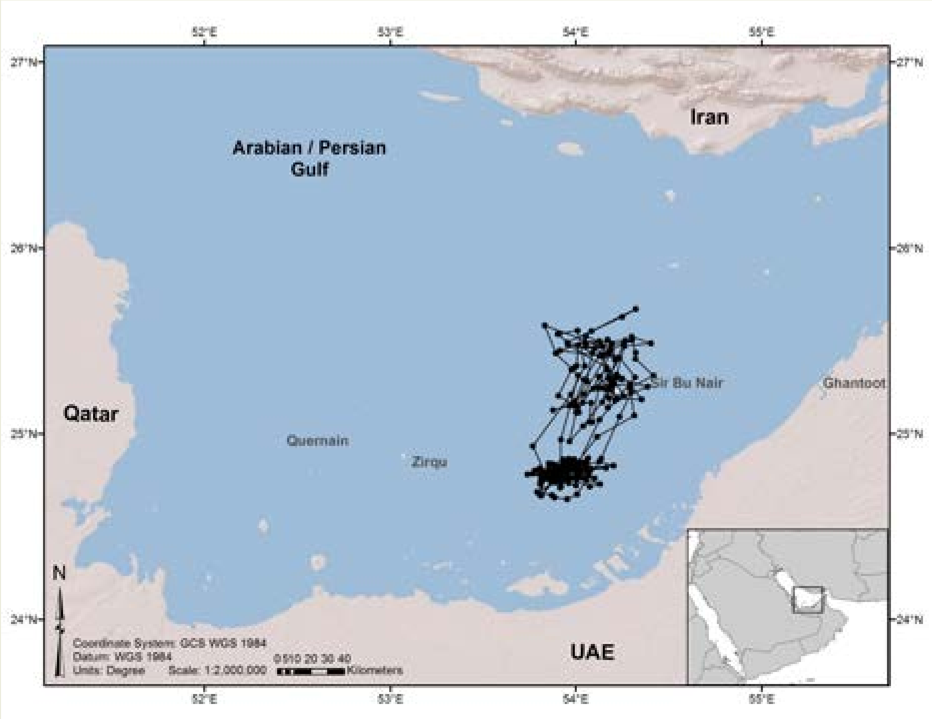
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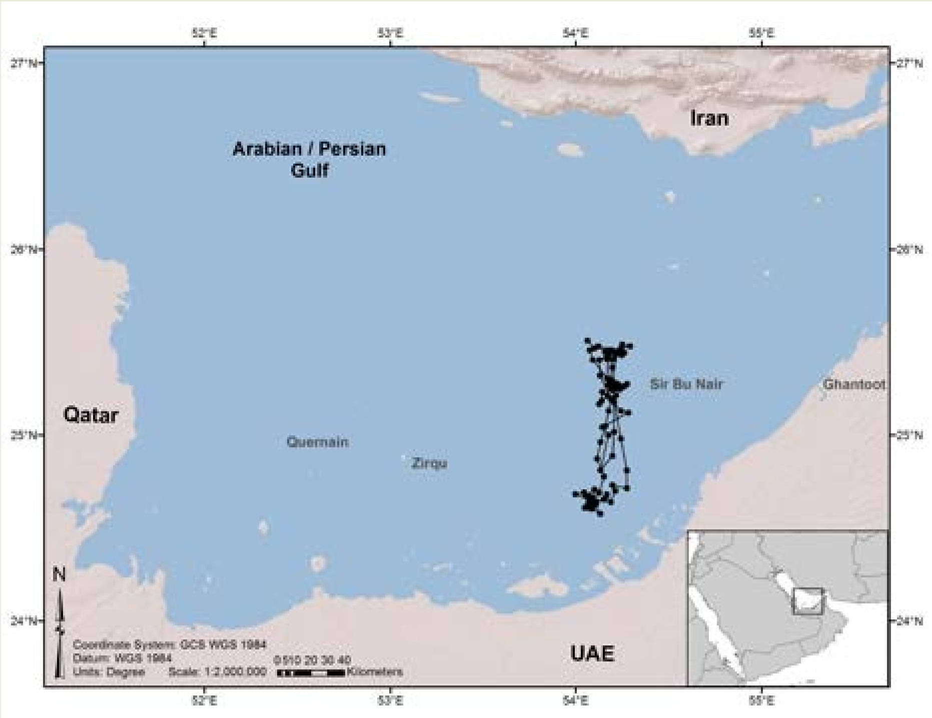
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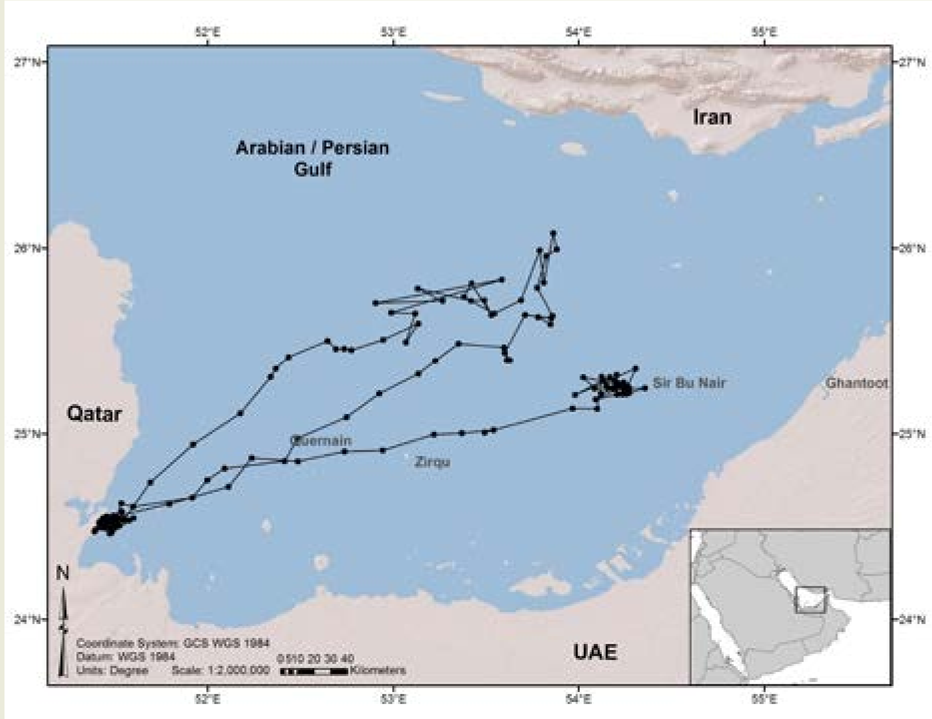
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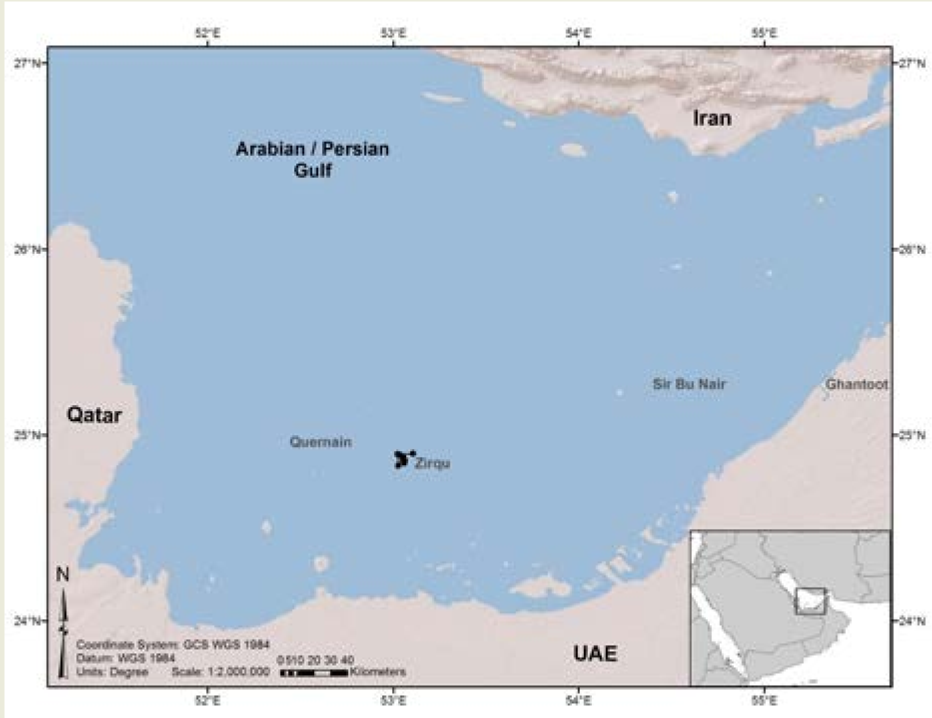
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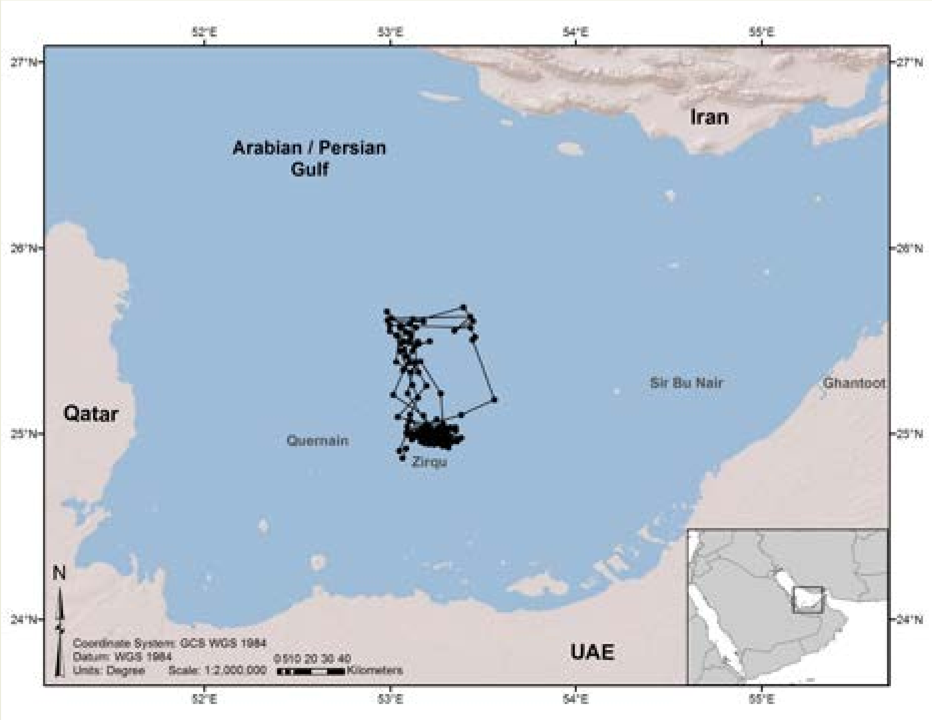
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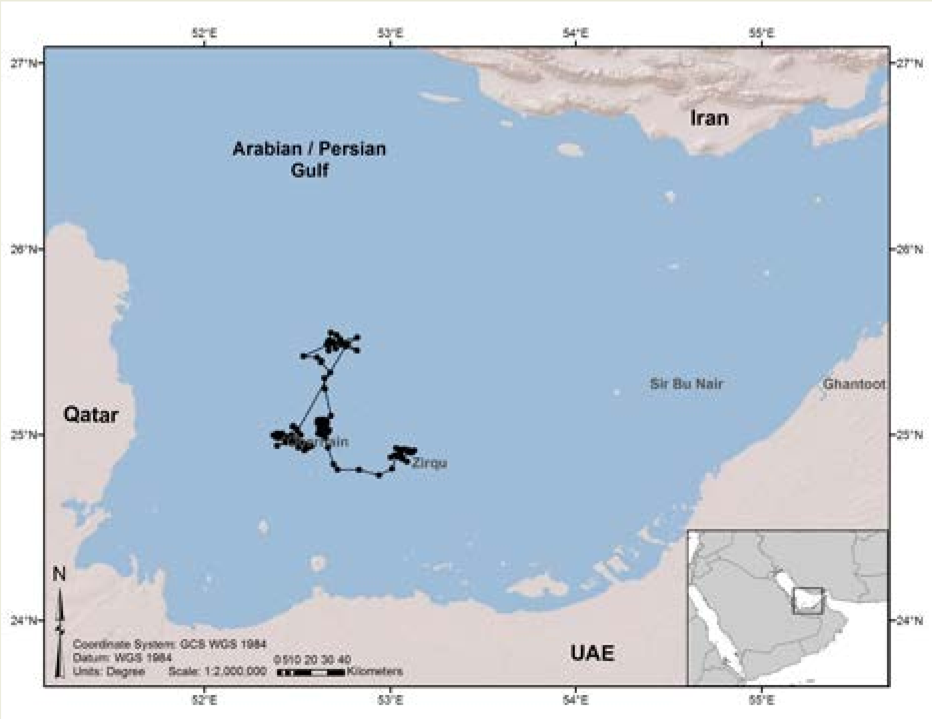
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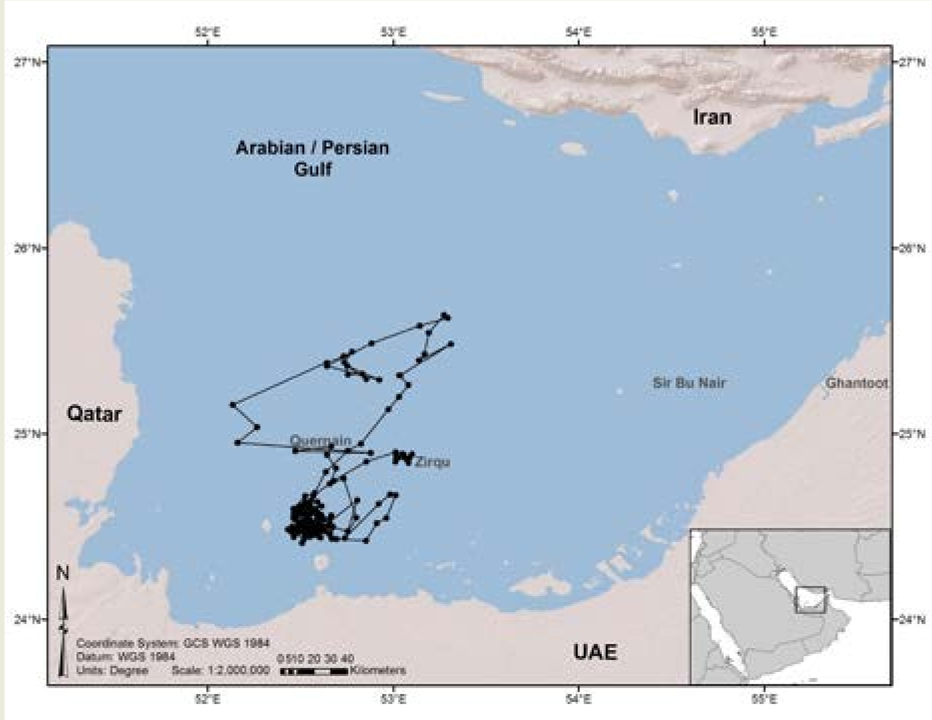
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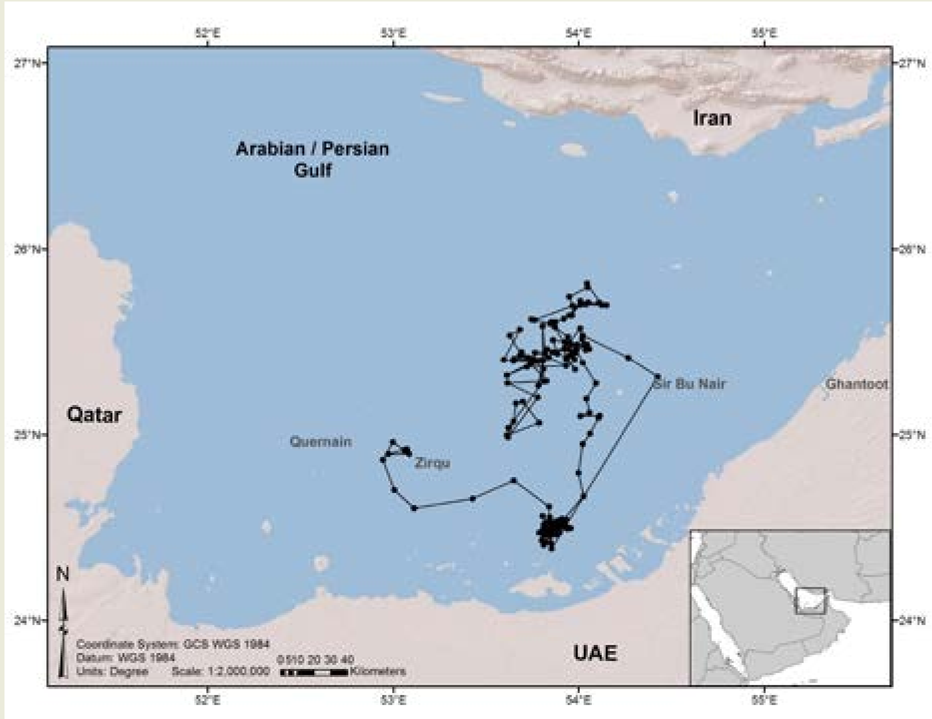
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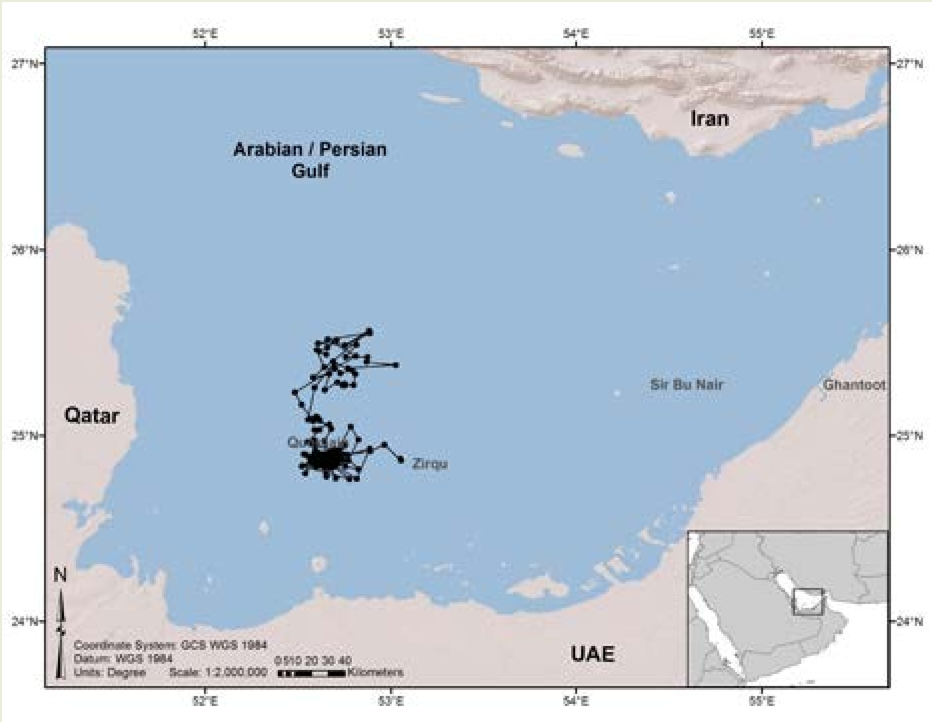
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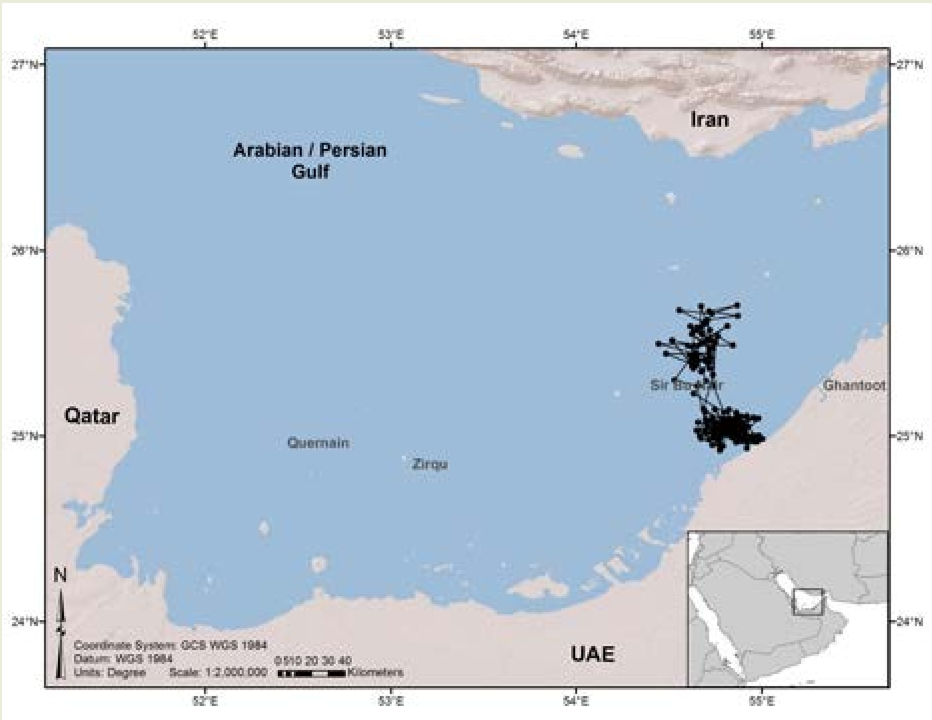
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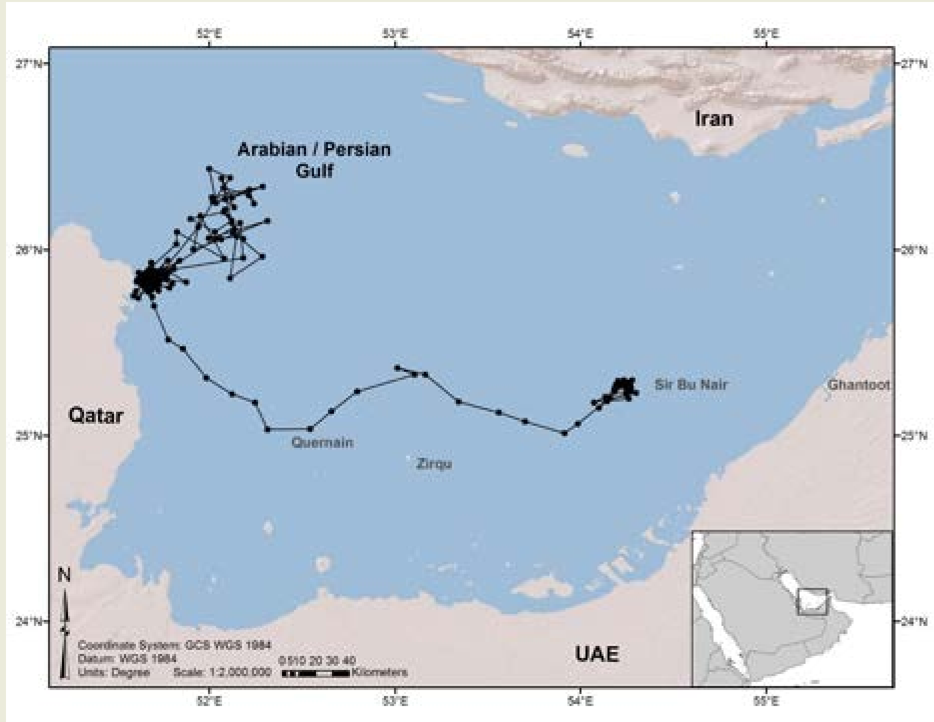
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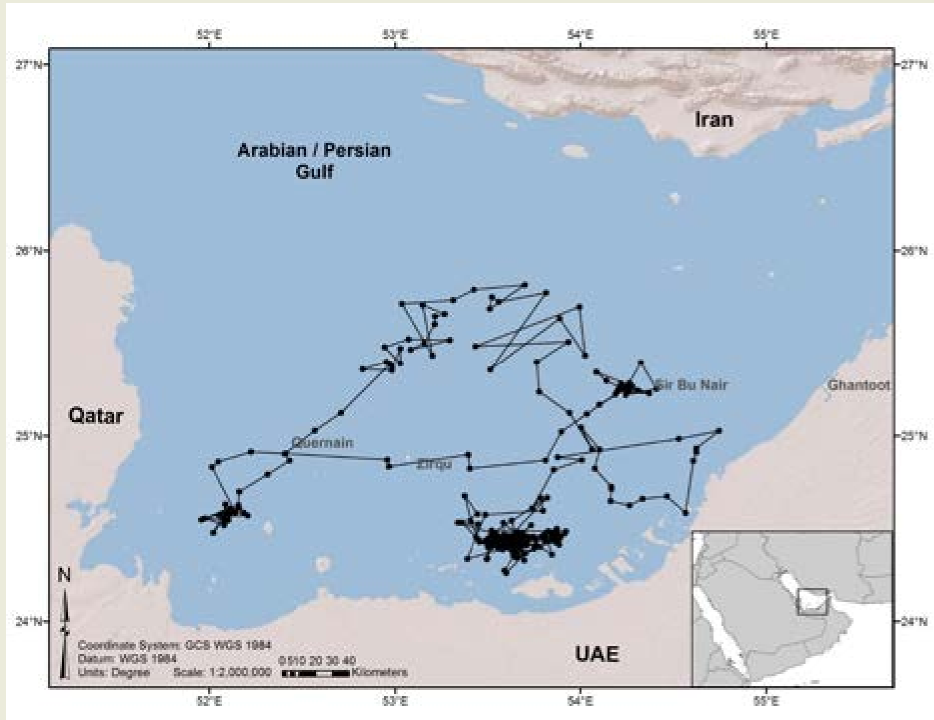
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ANNEX B

INDIVIDUAL DEPLOYMENT DATES AND SITES, NUMBER OF DAYS AND PROPORTION OF TIME SPENT IN EACH ACTIVITY.

Turtles which did not complete the migration and settlement at foraging grounds and excluded from time allocation calculations.

- Excluded from calculations for summer migrations.

Year	Country	Tag ID	Rookery	Date Deployed	Last Signal	# of Days / Proportion of Time								
						Nesting		Migrating		Feeding		Summer		Total
1999	UAE	10511	Quernain	11 May 99	28 Nov 99	0	0%	7	3%	110	56%	79	40%	196
		10512	Quernain	11 May 09	18 Mar 00	15	5%	8	3%	186	61%	95	31%	305
2007	Oman	74305	Daymaniyat#	10 May 07	30 Dec 07	34	15%	16	7%	180	78%	0	0%	230
		74036	Daymaniyat#	10 May 07	20 Sep 07	9	8%	68	56%	44	37%	0	0%	121
2010	Iran	52975	Sheedvar	19 Apr 10	05 May 13	35	3%	23	2%	1053	95%	0	0%	1111
		52976	Sheedvar	19 Apr 10	28 Sep 11	22	4%	16	3%	453	87%	31	6%	522
		52977	Sheedvar	19 Apr 10	19 Sep 10	22	15%	29	19%	37	25%	63	42%	151
		52978	Sheedvar	19 Apr 10	13 Jun 11	10	2%	20	5%	286	69%	96	23%	413
		52979	Sheedvar	19 Apr 10	30 Jul 11	34	7%	10	2%	420	91%	0	0%	464
	UAE	52981	Jebel Ali	07 May 10	14 Oct 10	4	3%	6	4%	120	78%	24	16%	154
		52982	Sir Bu Nair	10 May 10	26 Apr 12	31	4%	5	1%	621	88%	51	7%	708
		52983	Sir Bu Nair	10 May 10	25 Mar 11	15	5%	5	2%	248	79%	44	14%	312
		52984	Sir Bu Nair	10 May 10	16 Nov 10	0	0%	17	9%	60	33%	108	58%	185
		52989	Sir Bu Nair	10 May 10	03 Nov 11	7	1%	4	1%	408	76%	116	22%	535
	Oman	52999	Daymaniyat#	03 May 10	02 Mar 11	5	2%	55	19%	236	80%	0	0%	296
		53002	Daymaniyat#	03 May 10	07 Feb 11	8	3%	33	14%	189	82%	0	0%	230
		53003	Daymaniyat*#	03 May 10	08 Jul 10	0	0%	31	48%	33	52%	0	0%	64
		53006	Daymaniyat#	03 May 10	13 Feb 11	3	1%	22	8%	259	91%	0	0%	284
		53012	Daymaniyat#	03 May 10	30 Jan 11	0	0%	3	1%	265	99%	0	0%	268
	Qatar	53009	Fuwairit	13 May 10	23 Jan 11	0	0%	11	6%	100	50%	91	45%	202
		53010	Fuwairit	12 May 10	06 Jul 10	0	0%	4	9%	40	91%	0	0%	44
		53011	Ras Laffan	13 May 10	20 Jul 11	0	0%	155	37%	173	41%	93	22%	420
		53013	Fuwairit	13 May 10	10 May 11	2	0%	67	19%	237	67%	48	14%	354
		53015	Ras Laffan	14 May 10	23 Apr 11	13	4%	6	2%	233	69%	87	26%	340
2011	Oman	105834	Daymaniyat#	12 Apr 11	11 Oct 11	0	0%	24	14%	148	86%	0	0%	172
		105835	Daymaniyat#	13 Apr 11	23 Jan 12	45	16%	24	9%	211	75%	0	0%	280
		105836	Daymaniyat*#	13 Apr 11	04 May 11	0	0%	18	100%	0	0%	0	0%	18
		105837	Masirah#	17 Apr 11	25 Jun 12	0	0%	19	4%	402	96%	0	0%	420
		105838	Masirah*#	17 Apr 11	21 Jun 11	0	0%	2	3%	56	97%	0	0%	58
		105840	Masirah*#	17 Apr 11	03 Jun 11	0	0%	2	5%	42	95%	0	0%	44
		105841	Masirah#	17 Apr 11	26 Dec 11	0	0%	16	7%	225	93%	0	0%	241
	UAE	105842	Sir Bu Nair	21 Apr 11	24 May 12	25	6%	11	3%	325	83%	30	8%	390
		105843	Sir Bu Nair	21 Apr 11	28 Dec 12	0	0%	0	0%	373	77%	113	23%	486
		105844	Sir Bu Nair	21 Apr 11	05 May 13	46	6%	162	20%	514	64%	83	10%	806
		105850	Quernain	01 May 11	25 Nov 12	17	8%	4	2%	134	60%	69	31%	224
		105851	Quernain	01 May 11	19 Aug 11	2	2%	13	12%	88	86%	0	0%	103
		105852	Quernain	09 May 11	04 Dec 12	28	5%	3	1%	360	63%	178	31%	568
		105853	Quernain	09 May 11	04 Sep 12	76	16%	0	0%	308	64%	97	20%	481
	Qatar	105845	Fuwairit	27 Apr 11	16 Apr 12	23	7%	3	1%	253	73%	68	20%	347
		105846	Fuwairit	29 Apr 11	26 Sep 11	42	29%	5	3%	41	29%	56	39%	144
	Qatar	105847	Fuwairit	29 Apr 11	29 Aug 11	20	17%	3	3%	53	45%	43	36%	119
		105848	Ras Laffan	30 Apr 11	12 Dec 12	32	5%	9	2%	441	75%	103	18%	585
		105849	Fuwairit	26 Apr 11	21 Apr 13	27	4%	9	1%	630	88%	53	7%	719
		73008	Fuwairit	09 May 11	17 Aug 12	11	2%	8	2%	371	81%	69	15%	459
		73011	Fuwairit	04 May 11	13 Jul 12	14	3%	6	1%	355	82%	55	13%	430
		73014	Fuwairit	10 May 11	06 Nov 11	27	15%	13	7%	35	20%	103	58%	178
		73015	Fuwairit	09 May 11	11 Nov 12	24	4%	3	1%	441	82%	73	14%	541
		73016	Ras Laffan	20 May 11	18 Oct 11	18	6%	5	2%	214	71%	63	21%	300
	Iran	105854	Nakhiloo	09 May 11	20 Feb 13	2	0%	26	4%	520	81%	92	14%	641
		105855	Nakhiloo	09 May 11	06 Sep 11	10	9%	31	26%	30	26%	46	39%	117
		105856	Nakhiloo	09 May 11	03 Aug 12	3	1%	11	2%	436	97%	0	0%	450
		105857	Nakhiloo	10 May 11	04 Jun 12	8	2%	22	6%	222	57%	136	35%	388
		105858	Nakhiloo	10 May 11	11 Nov 11	15	8%	11	6%	157	86%	0	0%	183
2012	Oman	115249	Daymaniyat#	19 Apr 12	12 Dec 12	1	0%	44	19%	180	80%	0	0%	225
		115250	Daymaniyat#	19 Apr 12	06 Dec 12	17	8%	45	20%	161	72%	0	0%	223
		115251	Daymaniyat#	21 Apr 12	28 Mar 13	18	5%	40	12%	274	83%	0	0%	331
		115252	Daymaniyat#	21 Apr 12	06 Sep 12	17	12%	37	27%	84	61%	0	0%	139
		115253	Daymaniyat#	21 Apr 12	18 Dec 12	39	16%	19	8%	183	76%	0	0%	241
		115254	Masirah#	23 Apr 12	11 Dec 12	0	0%	27	12%	196	88%	0	0%	223
		115255	Masirah#	23 Apr 12	10 Jan 13	0	0%	2	1%	253	99%	0	0%	255
		115256	Masirah#	24 Apr 12	26 Aug 12	26	21%	7	5%	93	74%	0	0%	126
		115257	Masirah*#	24 Apr 12	07 Jul 12	0	0%	3	4%	68	96%	0	0%	71
		115258	Masirah#	24 Apr 12	04 Sep 12	0	0%	4	3%	125	97%	0	0%	129
		118976	Masirah#	31 May 12	14 Sep 12	1	1%	15	16%	82	83%	0	0%	98
	UAE	115259	Jebel Ali	26 Apr 12	06 May 13	34	9%	15	4%	245	67%	74	20%	368
		115260	Sir Bu Nair	02 May 12	30 Apr 13	15	3%	4	1%	356	76%	92	20%	466
		115261	Sir Bu Nair	03 May 12	08 May 13	22	5%	8	2%	344	74%	89	19%	463
		115262	Sir Bu Nair	03 May 12	01 Sep 12	26	22%	6	5%	31	27%	54	46%	117
		115263	Sir Bu Nair	03 May 12	08 May 13	40	9%	12	3%	318	68%	94	20%	464
		115271	Zirqu*	23 May 12	03 Jun 12	10	100%	0	0%	0	0%	0	0%	10
		115272	Zirqu	23 May 12	08 May 13	1	0%	1	0%	308	81%	70	18%	380
		115273	Zirqu	24 May 12	03 May 13	24	8%	7	2%	233	79%	33	11%	297
		115274	Zirqu	24 May 12	08 May 13	15	3%	4	1%	349	78%	77	17%	446
		115275	Zirqu	24 May 12	07 May 13	13	3%	7	2%	261	59%	161	36%	442
		115276	Zirqu	25 May 12	08 May 13	2	0%	5	1%	347	80%	78	18%	432
		115277	Jebel Ali	22 May 12	08 May 13	45	11%	0	0%	290	70%	78	19%	413
		115278	Sir Bu Nair	26 May 12	27 Mar 13	32	11%	18	6%	205	68%	45	15%	300
		115279	Sir Bu Nair	27 May 12	08 May 13	28	6%	11	3%	305	69%	98	22%	442
	Qatar	115264	Ras Laffan	11 May 12	27 Nov 12	42	21%	5	3%	101	50%	52	26%	199
		115265	Fuwairit	06 May 12	23 Mar 13	32	10%	69	22%	217	68%	0	0%	318
		115266	Fuwairit	07 May 12	07 May 13	32	7%	14	3%	336	73%	79	17%	461
		115267	Fuwairit	08 May 12	09 May 13	29	6%	2	0%	374	81%	55	12%	460
		115268	Fuwairit	08 May 12	21 Jan 13	28	11%	4	2%	177	70%	44	17%	253
		115269	Fuwairit	09 May 12	07 Jan 13	33	14%	16	7%	130	55%	59	25%	238
		115270	Fuwairit	09 May 12	23 Sep 12	3	2%	33	25%	97	73%	0	0%	133
		119857	Fuwairit	18 May 12	07 Aug 13	16	3%	18	3%	448	88%	29	6%	511
		119858	Fuwairit	24 May 12	29 Apr 13	24	7%	4	1%	275	80%	41	12%	344
		119859	Ras Laffan*	25 May 12	11 Aug 12	37	45%	18	22%	27	33%	0	0%	81
		119860	Ras Laffan	25 May 12	08 Aug 13	6	1%	28	6%	360	71%	115	23%	510
		119861	Fuwairit	27 May 12	05 Jun 13	27	7%	8	2%	315	83%	32	8%	382
		Gulf Turtles		**Average**			**6.3%**		**4.9%**		**68.0%**		**20.4%**	
				SD			**5.97**		**6.17**		**17.97**		**14.13**	
				Minimum			**0.0%**		**0%**		**20%**		**0%**	
				Maximum			**29.4%**		**26%**		**97%**		**58%**	
		Oman Turtles		**Average**			**4.6%**		**12.7%**		**82.9%**			
				SD			**6.03**		**12.21**		**14.57**		**N/A**	
				Minimum			**0.0%**		**0%**		**37%**			
				Maximum			**16.3%**		**56%**		**100%**			

بحث

از آنجایی که دمای آب‌های سطحی در خلیج‌فارس در ماه‌های زمستان به ۱۶ درجه سانتی‌گراد و در ماه‌های تابستان به حداکثر ۳۷ درجه سانتی‌گراد می‌رسد، این احتمال وجود دارد که اندازه کوچکتر لاکپشت‌های دریایی در خلیج فارس مرتبط به شدت درجه حرارت در مواقع سرد و گرم باشد. قرار گرفتن در معرض دماهایی که از معمول حد توان لاکپشت‌ها فراتر می‌رود، می‌تواند منجر به کاهش دریافت مواد غذایی و رشد لاکپشت‌ها گردد. همچنین دمای سرد زمستانی باعث خیرگی از سرمای خیلی از لاکپشت‌های کوچکتر می‌گردد. لاکپشت‌های خلیج‌فارس جزو کوچک‌ترین لاکپشت‌های بالغ جهان محسوب می‌شوند که اشاره بدان دارد که رشد لاکپشت‌های خلیج با کمبود موادغذایی محدودگردیده است.

داده‌های مرتبط با زاد و ولد کلی خروجی در حوزه منطقه‌ای می‌تواند به کسب درکی از قوت جمعیت لاکپشت‌ها کمک‌کند و به مدیران و فعالان حفظ محیط‌زیست کمک کند که عملکرد جعیت را در طول زمان پیگیری کنند. تفسیر داده‌های تلمتری می‌تواند منجر به برآوردهای دقیقی از تواتر لانه‌گزینی گردد. در این مطالعه نشان داده شده که لاکپشت‌های عمان به طور میانگین تخم کمتری از لاکپشت‌های خلیج‌فارس می‌گذارند. با توجه به دوره‌های حبس در نواحی مورد توجه پس از رهاسازی فرستنده‌ها، تخمین ما این است که لاکپشت‌ها بالقوه تا پنج‌تخم اضافه (برای مجموع شش تخم) می‌گذارند. اگرچه به طور معمول در هر فصل سه تخم می‌گذارند.

معمولا الگوهای گردش آب در خلیج فارس قوی نیستند و میانگین سرعت آنها تنها ۰/۱ کیلومتر بر ساعت است، و ما بدین ترتیب تاثیر آن‌ها بر الگوهای مهاجرت پس از لانه‌گزینی لاکپشت‌ها در خلیج را کم در نظر گرفتیم. این گونه به نظر می‌رسد که اندازه کوچکتر لاکپشت‌های منقاردار خلیج، تاثیر چندانی بر روی توانایی شناکردن آن‌ها نداشت. میانگین مسافت‌های طی شده مهاجرت‌ها در خلیج به میزان زیادی از میانگین جهانی پایین‌تر بود. این امر انعکاسی از اندازه کوچک خلیج‌فارس و همچنین عدم مهاجرت لاکپشت‌های خلیج به دریای عمان و ماورای آن است. در خلیج، مهاجرت لاکپشت‌های بالغ از سمت شرقی خلیج به سمت جنوب و جنوب‌غربی تمایل داشت که بر خلاف گردابه‌های مرکزی خلیج است. شماری از لاکپشت‌ها از شمال قطر به جانب جنوب و جنوب‌غربی و در جهت جریان‌های آبی مهاجرت کردند ولی تعداد قابل‌ملاحظه‌ای نیز به جانب شمال و شمال‌غربی در جهت خلاف جریان‌های آبی، از محل‌های لانه‌گزینی مهاجرت کردند. سه لاکپشت که در حال مهاجرت از قطر به بحرین بودند، از خود گرایش برای ورود به خلیج سلوی نشان دادند. با توجه به مذاکرات برای ایجاد یک جاده برای اتصال این دو کشور، به نظر ما این منطقه‌ای نگران کننده‌ای از لحاظ حفاظت (از لاکپشت‌ها) است، چرا که می‌تواند یک گلوگاه مهاجرتی بین این دو نقطه‌ی عطف ایجاد کند.

به نظر می‌رسد که جریان سومالی، از دریای عربی، مانع شنای هدفمند ثبت‌شده‌ی لاکپشت‌های دریای عمان، حتی لاکپشت‌های منقار دار که جزو گونه‌های کم‌تحرک‌تر محسوب می‌شوند، نشد. طول مسیر مهاجرت لاکپشت‌هایی که جزایر دیمنیه را ترک می‌کردند دو برابر میانگین جهانی لاکپشت‌های منقار دار بود و به ماکزیمم طول مسیر ۱۱۰۰ کیلومتر رسید. لاکپشت‌هایی که مصیره را ترک می‌کردند مسیرهای بسیار کوتاهتری از میانگین جهانی را طی کردند و میانگین طول مسیر مهاجرتشان به ۸۰/۵ کیلومتر رسید. اگرچه تمام این لاکپشت‌ها به غیر از یکی به سمت سرزمین اصلی عمان رفتند و میانگین جابجایی آن‌ها تنها ۳۰ کیلومتر بود که به شدت از میناگین جهاین ۳۲۷ کیلومتر پایین تر است. به نظر ما گلوگاه این ناحیه در راس‌الحد واقع شده که به دلیل میزان بالای ماهیگیری سنتی و صنعتی در این ناحیه مایه‌ی نگرانی است. همه‌ی لاکپشت‌هایی که از جزایر دیمنیه حرکت کرده بودند، به غیر از یکی، راس را دور زدند و به جانب جنوب‌غربی و به سمت مصیره و ماورای آن حرکت کردند. بدین ترتیب پیشنهاد ما این است که این ناحیه به عنوان یک مسیر حیاتی برای لاکپشت‌های منطقه در نظر گرفته شود. به همین ترتیب پیشنهاد می‌کنیم که در عمان، ناحیه بین نوک جنوبی جزایر مصیره و شانا در سرزمین اصلی به عنوان یک مسیر مهم مهاجرتی و تغذیه‌ای در نظر گرفته شود.

نتایج ما نشان می‌دهد که لاکپشت‌های منقار دار خلیج از واکنش‌های تنظیم حرارتی استفاده می‌کنند که آن‌ها را از آب‌های گرم و شرایطی که بالقوه از لحاظ فیزویولوژیکی برایشان مخاطره‌آمیز هستند دور می‌کند. دمای سطح آب در تابستان به طور میانگین ۳۳/۵ درجه و در بالاترین نقطه به ۳۴/۹ درجه سانتی‌گراد رسید. در این زمان‌های طولانی که دمای هوا بالا بود (از ژون تا اوت)، لاکپشت‌ها موقتا، به طور میانگین ۷۰ کیلومتر به سمت شمال و آب‌های عمیق‌تر مهاجرت کردند و بعد از ۲ تا ۳ ماه (سپتامبر تا اکتبر) به مکان‌های تغذیه اولیه بازگشتند. تفاوت دما بین بستر‌های تغذیه‌ای و حلقه‌مهاجرت تابستانه بسیار متفاوت بود و حدوداً −۲ درجه سانتی‌گراد بود. لاکپشت‌ها در حلقه‌مهاجرت تابستانه به طور کلی به سمت شمال‌شرقی به آب‌های عمیق‌تر می‌رفتند و در بازگشت در جهت جنوب‌غربی به بسر‌های تغذیه‌ای مهاجرت می‌کردند. سرعت شنا در زمان مهاجرت نسبت به زمان تغذیه بسیار بالاتر و کمتر چندسویه بود. مهاجرت‌های برون‌رو به شکل چشمگیری با

دما نسبت عکس داشت، ولی با کلروفیل–آ، جریان‌های زمین‌گرد و ارتفاع سطح آب نسبتی نداشت. رفتارهای تنظیم دمایی در لاکپشت‌های خارج از خلیج مشاهده نشد و اعتقاد ما بر این است که این امر نتیجه آب‌های معتدل اقیانوس هند باشد که در آنجا فلات قاره، در امتداد ساحل عمان، اثرات آبهای سرد را تا نزدیکی ساحل می‌آورد.

لاکپشت‌های ناحیه خلیج ۷۰ درصد وقت خود را در بستر‌های تغذیه‌ای سپری کردند و لاکپشت‌های ناحیه عمان ۸۳ درصد وقت را به جستجوی غذا سپری کردند. علت تفاوت این اختصاص دو مقدار متفاوت زمان در این است که لاکپشت‌های خلیج مهاجرت‌های تابستانی انجام می‌دهند تا از گرمای آب‌های سطحی، در ماه‌های تابستانی، نجات پیدا کنند. باور ما بر این است که لاکپشت‌ها در این دوره تغذیه نمی‌کردند. زیستگاه‌های جستجوی غذا در نواحی پهناوری گسترده شده بودند، ولی در سطح یک لاکپشت، بین ۴۰ تا ۶۰ کیلومتر مربع بودند و مساحت هسته تنها ۳ تا ۵ کیلومتر مربع بود. گستره خانه و نواحی هسته برای لاکپشت‌های عمانی بسیار کوچک‌تر از لاکپشت‌های خلیج بود. این امر حاکی از آن است که لاکپشت‌های عمان نسبت به لاکپشت‌های خلیج که در آب و هوای سخت‌تری به سر می‌برند، دسترسی به نواحی جستجوی غذا با کیفیت بالاتری دارند و این امر نیاز آن‌ها را به حرکت بالا برای جستجوی غذا را کم می‌کند. داده‌های نمونه‌برداری حاکی از آن است که این نواحی ممکن است محدود به تپه‌های صخره‌ای کوچکی باشد که چندصد متر پهنا دارند. در گوشه جنوب‌غربی خلیج بستر‌های جستجوی غذا در فضایی به وسعت ۲۰,۰۰۰ کیلومتر مربع بین ابوضبی در امارات‌متحده‌عربی، تکه‌ی کوچکی از آب‌های ارضی عربستان‌سعودی، و قسمت جنوبی قطر گسترده شده‌اند. در عمان زمین‌های جستجوی غذا در فاصله بیش از ۵۰۰ کیلومتر از ساحل گسترده شده‌اند که با توجه به شیب سریع به عمق زیاد، در نزدیکی عمان زیستگاه‌های لاکپشت‌ها به کمربند باریک ساحلی محدود شده است.

بر خلاف انتظار قبلی ما مبنی بر اینکه لاکپشت‌های منقار دار خلیج، زیستگاهی در نواحی مشخص دارند، که می‌توان آن‌ها را برای سطحی از محافظت نشانه‌گذاری کرد، (این مطالعه نشان می‌دهد) گستره‌ی وسیع پراکندگی لاکپشت‌های منقاردار در جنوب‌غربی خلیج تصمیم‌گیری مدیران برای محافظت از آن‌ها را چالش برانگیز می‌کند. شاید اینکه زیستگاه‌های تغذیه‌ای لاکپشت‌های منقاردار غالباً در نواحی ساحلی و آب‌های کم‌عمق که مشترک با کشتی‌ها تجاری است، مشکل چندان مهمی نباشد، ولی از این نواحی بیشتر برای ماهیگری سنتی استفاده می‌شود. ساخت سازهای تجاری و مسکونی در آب‌های کم عمق بایستی به منظور حفاظت از نواحی تغذیه‌ای لاکپشت‌های منقاردار محصور گردد. همچنین به منظور وضع قوانین و اینجاد برنامه‌های حفاظتی برای بقای لاکپشت‌های منقاردار، بایستی اثر ماهیگیری بر روی لاکپشت‌های منقاردار مورد مطالعه قرار گیرد. در عمان تشخیص نواحی مهم لاکپشتی بسیار ساده تر بود که شامل شناسایی شانا و غویرة به عنوان زیستگاه‌های کلیدی تغذیه‌ای، و آب‌های راس‌الحد (در واقع نوار ۲۰ کیلومتری در راستای سواحل بین جزایر دیمنیه، مسقط و جزیره مصیره) به عنوان گلوگاه مهم حفاظتی برای لاکپشت‌های منقار دار بود.

ماهیگیری‌های سنتی در مقیاس کوچک، بالقوه توانایی تاثیرگزاری منفی شدید بر لاکپشت‌های دریایی دارند. در این مطالعه ردیابی ماهواره‌ای نشان از مرگ‌ومیر دو لاکپشت از ۹۰ لاکپشت داشت. این امر حاکی از آن است که مرگ‌ومیر ناشی از ماهیگیری یکی از دغدغه‌های حفاظتی در این منطقه است. با توجه به گستره پراکندگی لاکپشت‌های منقاردار و دیگر لاکپشت‌ها در این ناحیه، به نظر می‌رسد که بهترین راه حل حفاظت، مدیریت ماهیگری است. همچنین نگاهی جدی به اثر ماهیگیری در سطح منطقه‌ای نیاز است.

نتایج کار ما می‌تواند مورد استفاده دولت‌ها و آژانس‌های حفاظتی در فرمتی همساز با سیستم اطلاعات جهانی قرار گیرد تا ارزیابی ریسک برای لاکپشت‌ها در مقابل ساخت و ساز‌های مسکونی و صنعتی شامل صنایع نفت و گاز، تغییرات آب و هوایی، فشار ماهیگیری، و فعالیت‌های کشتیرانی را تسهیل گرداند. این ارزیابی‌های ریسک برای لاکپشت‌ها، می‌تواند به برجسته‌سازی همپوشانی نواحی مهم لاکپشتی، و خطر‌های گوناگونی که در ناحیه عربی وجود دارد، کمک کند. همچنین می‌تواند مسیری برای الویت‌بندی نواحی مهم لاکپشتی برای فعالیت‌های اختصاصی حفاظتی و مدیریتی فراهم کند.

شناسایی نواحی کلیدی جستجوگری، الگوهای زمانی فعالیت و تنگناهای بالقوه مهاجرتی استفاده شده است. امید است که این داده‌ها و آنالیز آن‌ها با شناخت بهتری از زیستگاه و رفتار لاکپشت‌های منقاردار در آب‌وهوای چالش برانگیز ایجاد کند و به درک بهتر ما از نواحی مهم لاکپشتی در منطقه عربی کمک کند، و باعث حمایت از سیاست‌های حفاظتی از لاکپشت‌های دریایی در سطوح ملی و منطقه‌ای گردد.

اسلوب مطالعه

فرستنده‌های ماهواره‌ای توسط فایبرگلاس و رزین به لاکپشت‌ها وصل شد. به علاوه، به منظور شناسایی پشتیبان، هر لاکپشتی نشانه‌گذاری، اندازه گیری و همچنین نمونه برداری از بافت برای آنالیز ژنتیکی شد. ما داده‌ها را به گونه‌ای فیلتر کردیم که محل‌های تثبیت با سرعت کمتر از ۵ کیلومتر در ساعت و همچنین داده‌های غیر محتمل از قبیل محل‌های تثبیت محصور در خشکی و همچنین مکان‌های تثبیتی که هزاران کیلومتر از محل قبلی فاصله داشتند، حذف گردند. ما هر روز تنها یک محل تثبیت به ازای هر لاکپشت در روز را ضبط کردیم به صورتی که با کیفیت‌ترین داده در روز را انتخاب کرده باشیم. در مواردی که بیش از یک سیگنال با کیفیت بالا در اختیار داشتیم، سیگنال نزدیکتر به نیمروز را انتخاب کردیم. تمام نقاط پیش از ترک لانه به عنوان نقاط جالب توجه دسته‌بندی شدند. افزایش سرعت و فرض حرکت در یک جهت تا رسیدن به محل خوراک به عنوان مهاجرت دسته‌بندی گردید. زمین‌های تغذیه به واسطه‌ی کاهش در سرعت حرکت و همچنین تغییر نوع حرکت از حرکت یکسویه‌ی هدفدار به حرکت‌های کوتاه در جهات تصادفی شناسایی شدند. حرکت‌های هدفمند به جانب شمال‌شرق در میانه خلیج در ماه‌های جولای تا اوت و به دنبال آن بازگشت در ماه‌های سپتامبر تا اکتبر به عنوان مهاجرت تابستانه دسته‌بندی گردیدند. برای توصیف گستره‌ی نواحی جستجوگری هر لاکپشت و شناسایی مناطق مهم لاک‌پشتی، ما گستره زمین خانه (۹۵ درصد فشردگی تثبیت سیگنال مکان‌های جستجوگری غذایی) و نواحی هسته (۵۰ درصد تثبیت سیگنال مکان جستجوی غذا) را محاسبه کردیم.

برای توصیف محیط‌زیست دریایی در مکان‌های جستجوگری تغذیه‌ای و در دوران مهاجرت، ما همچنین داده‌های زیست‌محیطی فیزیکی و بیولوژیکی را از راه دور اندازه‌گیری کردیم که شامل دمای سطحی دریا و ارتفاع سطح دریا، جریان‌های زمین‌گردی، همراه با تراکم کلروفیل سطحی می‌گردد. ما داده‌های مربوطه زیست‌محیطی و بیولوژیکی نسبت به موقعیت فضایی هر لاکپشت را استخراج کردیم. این موقعیت فضایی توسط میان‌یابی بین نقاط شبکه با رزولوشن یکسان با متغیرهای محیطی و زمانی صورت گرفته. همچنین رابطه‌ی بین این متغیرها و محل تثبیت مکانی لاکپشت‌ها، حالات رفتاری، زمان تغییرات رفتاری به منظور توضیح پاسخ‌های رفتاری لاکپشت‌ها مورد استفاده قرار گرفته است.

نتایج مطالعه

با توجه به تفاوت‌های موجود در مهاجرت و الگوهای رفتاری شناسایی‌شده بین خلیج، مصیره و جزایر دیمنیه در آنالیزمان معمولاً این نواحی را به طور جداگانه در نظر گرفتیم. ما تفاوت قابل ملاحظه‌ای بین طول انحنای‌سخت‌پوستی[1] (سی‌سی‌ال) بین لاکپشت‌های ناحیه خلیج و عمان مشاهده کردیم. سی‌سی‌ال لاکپشت‌های ناحیه خلیج به طور میانگین ۷۰/۳ سانتی‌متر بود در حالی که لاکپشت‌های ناحیه عمان حدود ۱۰ سانتی‌متر طویل‌تر و دارای سی‌سی‌ال میانگین ۸۰/۴ بودند.

زمان متوسط بین نشانه‌گذاری و مهاجرت لاکپشت‌ها در خلیج حدود ۲۰/۱ روز بود که نشانگر میانگین ۱/۴ دوره لانه‌گزینی همراه با ۰ تا ۵ اتفاق لانه‌گزینی بود. تفاوت فاحشی بین فعالیت لانه‌گزینی در لاکپشت‌های جزاری دیمنیه و مصیره مشاهده نشد و میانگین مرکب دوره لانه‌گزینی برای لاکپشت‌های عمان ۱۱/۱ روز بود که نشانگر ۰/۹ دوره سیکل لانه‌گزینی همراه با ۰ تا ۳ اتفاق لانه‌گزینی بود. به طورکلی یافته‌های ما نشان می‌دهد که لاکپشت‌های منقاردار ناحیه عربی قابلیت حداکثر ۶ بار لانه‌گزینی در فصل را دارا هستند (که توسط گروه ما و ۵ گروه دیگر مشاهده شده است). اگرچه به طور میانگین لانه‌گزینی ۳ بار در فصل اتفاق می‌افتد که نشانگر فعالیت لانه‌گزینی پایین‌تر در نواحی با تراکم جمعیت بالاتر لاکپشت‌ها در خلیج عمان و خلیج فارس است.

لاکپشت‌ها در خلیج عمدتا به سمت جنوب یا جنوب‌غربی و به سمت گوشه جنوب‌غربی خلیج که بین امارات

متحده عربی، عربستان سعودی و قطر مشترک است حرکت کرند. اگرچه بخش کوچکی از لاکپشت‌ها به خلیج فارس از سمت سلوی (بین قطر و عربستان سعودی) و شمال به سمت بحرین، عربستان سعودی و کویت سفر کردند. لاکپشت‌ها از جزایر دیمنیه به جهت جنوب‌شرقی و در امتداد ساحل دریای عمان، گرد راس‌الحد و به سمت جنوب‌غربی به سمت نواحی تغذیه‌ای بیرون از سواحل سرزمین اصلی نزدیک مصیره، بیشتر به سمت خط ساحلی یمن حرکت کردند. لاکپشت‌ها به ندرت بیش از ۵۰ تا ۸۰ کیلومتر از مصیره به سمت نواحی تغذیه‌ای بیرون از سرزمین اصلی عمان حرکت کردند. البته به اسنثنای یک لاکپشت که ۳۵۰ کیلومتر به سمت جنوب‌غربی سفر کرد.

مهاجرت لاکپشت‌های خلیج کوتاه بود و به طور میانگین طی ۱۰/۳ روز تکمیل می‌شد و مسافت میانگین ۱۸۹/۴ کیلومتر را شامل می‌شد. مهاجرت از جزایر دیمنیه طولانی‌ترین مهاجرت‌ها بود که به طور میانگین ۶۷۲/۶ کیلومتر بود و میانگین ۲۸/۶ روز به درازا می‌کشید. همه به استثنای ۲ عدد از این لاکپشت‌ها به جزایر مصیره در سواحل جنوبی عمان رسیدند و یا از آن عبور کردند. یکی از لاکپشت‌ها از راه تنگه‌هرمز به خلیج فارس مهاجرت کرد که اولین بار است که چنین مهاجرتی به ثبت رسیده است. در مقابل لاکپشت‌هایی که از مصیره حرکت کرده بودند کوتاه‌ترین مسیر مهاجرت را داشتند که طول میانگین آن ۳/۹۵ کیلومتر بود و ۸۰/۵ روز به درازا کشید. سرعت سفر لاکپشت‌ها در مهاجرت فرق چندانی بین خلیج، مصیره و جزایر دیمنیه نداشت و میانگین ۱۹/۰۲ کیلومتر در روز بود.

لاکپشت‌هایی که در حلقه‌های مهاجرت تابستانه حرکت می‌کردند، به طور کلی در مسیری به سمت شمال‌شرقی به طرف نواحی عمیق‌تر خلیج بین ماه‌های اوت و جولای سفر می‌کردند. مسیر بازگشت آنها در جهت جنوب‌غربی به سمت محل‌های تغذیه‌ای کم عمق‌تر خلیج در ماه‌های سپتامبر تا اکتبر بود. سرعت حرکت لاکپشت‌ها در حالت حلقه‌ی‌مهاجرت‌تابستانه به طرز قابل ملاحظه‌ای سریع‌تر از حالات قبل و بعد از آن بود، بدین ترتیب که لاکپشت‌های در حال جستجوی غذا با سرعت میانگینی حدود ۴/۶ کیلومتر در روز و آنهایی که در حلقه‌ی مهاجرت تابستانه حرکت می‌کردند سرعت میانگین ۱۰/۹ کیلومتر در روز داشتند. اصطلاح «حلقه‌مهاجرت‌تابستانه» از زمان کلی تغیرات رفتاری لاکپشت‌ها گرفته شده. این در زمانی است که لاکپشت‌ها از آب‌هایی که به طور قابل‌ملاحظه‌ای گرمتر بودند، به سمت آبهای که تقریبا ۲ درجه سانتی‌گراد سردتر بودند، در اوج حلقه مهاجرت حرکت می‌کردند، و تا خنک شدن قابل ملاحظه‌ی آب‌های جنوب‌غربی خلیج باز نمی‌گشتند.

در خلیج لاکپشت‌ها مکان‌های دنج و دورافتاده تغذیه‌ای را اشغال می‌کردند، و معمولا در دو سه ماه مهاجرت تابستانی به همان نواحی باز می‌گشتند ولی به کرات نیز به نواحی جدید نقل مکان می‌کردند. هیچ کدام از لاکپشت‌ها (به جز یکی) به سمت شرق و به سوی ایران، و یا به سمت نواحی شرقی امارات‌متحده‌عربی که آب‌های پاک‌تری از سوی دریای عمان دریافت می‌کنند، حرکت نکردند. در دریای‌عمان، لاکپشت‌ها از هر دوی جزایز دیمنیه و مصیره به آب‌های شنة، در سرزمین اصلی عمان و مجاور مصیره، چندصد کلیومتر (حدود ۲۵۰ تا ۳۰۰ کیلومتر) در جهت غويرة مهاجرت کردند.

سرعت حرکت لاکپشت‌ها در زمان تغذیه (=۴/۵ کیلومتر در روز) کمتر از زمان مهاجرت (=۱۹/۰۲ کیلومتر در روز) و یا حلقه‌ی مهاجرت تابستانه (=۱۰/۹ کیلومتر در روز) بود. گستره‌ی ناحیه خانه از لحاظ اندازه متفاوت بود، ولی به طور کلی کوچک بود و میانگین ۴۸/۷ کیلومتر مربع داشت. اکثر گستره نواحی خانه بین ۴۰ تا ۶۰ کیلومتر مربع بود. در مقابل نواحی هسته بسیار دقیق بودند که محدود به تکه‌های کم‌عمق می‌شدند که میانگینی حدود ۳/۳ کیلومتر مربع داشتند که اکثر آنها بین ۳ تا ۵ کیلومتر مربع وسعت داشتند. نواحی خانه در خلیج با میانگین ۵۲/۴ کیلومتر مربع از وسعت به مراتب بالاتری نسبت به نواحی خانه لاکپشت‌های بیرون خلیج با میانگین ۳۹/۷ کیلومترمربع برخوردار بودند. نواحی هسته نیز از الگوی مشابهی پیروی می‌کردند که اشاره‌گر کیفیت بالاتر زمین‌های تغذیه‌ای نزدیک اقیانوس هند در قیاس با نواحی با آب‌وهوای سخت خلیج می‌باشد.

دو لاکپشت اطلاعاتی را به دست دادند که اشاره به ماهیگیری دارد: یکی از آنها در نواحی دیمنية رها شده بود در مسیری به سمت جنوب‌غربی در جهت راس‌الحد در حرکت بود. پس از دور زدن به گرد کرت‌وکنار مسیر آن به سمت شمال‌شرقی و عبور از دریای عمان تغییر کرد. آنالیز داده‌های ردیابی نشان‌گر این بود که فرستنده‌ماهواره‌ای سیگنالی قوی را ارسال می‌کرد، اما تمام سیگنال‌ها از مکانی خشک فرستاده می‌شدند که نمایانگر این بود که لاکپشت باید بر روی یک کشتی باشد. سیگنال‌ها در میان راه بین عمان و پاکستان قطع شدند. لاکپشت دیگر به ناگاه زمین تغذیه را در میان خلیج فارس ترک کرد و به سمت شمال‌شرقی و به سوی ایران حرکت کرد. داده‌ها جمع‌آوری شده در شش ماه پس از آن نمایانگر این هستند که فرستنده در خشکی و در نزدیکی شهری به نام خشکنار بوده.

مستوى الكلوفويل والتيارات أو ارتفاع سطح البحر. لم يتم ملاحظة واكتشاف التصرف مع عوامل الحرارة لقد تم ملاحظ علاقة عكسية مع عوامل الحرارة في هجرة السلاحف خارج الخليج العربي وعدم وجود اي علاقة مع مستوى الكلوروفيل أو ارتفاع سطح البحر.لم يتم ملاحظة واكتشاف العلاقة بين تصرف السلاحف وعوامل الحرارة خارج الخليج العربي.ويعتقد بأن الارتفاع في حرارة مياه المحيط الهندي عند الطبقة الضيقة على امتداد السواحل العمانية تؤدي الى جذب المياه الباردة قراية الساحل.

تقضي السلاحف في الخليج العربي 70% من وقتها في مناطق التغذية، بينما تقضي السلاحف العمانية 83% من وقتها في مناطق التغذية. الفارق بين هذا الوقت هو نتيجة بأن سلاحف الخليج العربي تقوم بهجرة الصيف للهروب من درجات سطح الماء المرتفعة خلالٍ أشهر الصيف، والتي نعتقد بأنها لا تتغذى خلال هذه الفترة. تنتشر مناطق التغذية في مناطق واسعة جداً، ولكن على المستوى الفردي للسلحفاة تكون في مجال يفوق 40–60 كيلومتر مربع، مع منطقة محورية تبلغ 3–5 كيلو متر مربع فقط. مجال المنطقة والمناطق المحورية لسلاحف العمانية كان أقل نسبياً من مناطق سلاحف الخليج العربي، مما يقترح بأن سلاحف عمان لها فرص أكثر لمناطق تغذية أفضل مقارنة مع سلاحف الخليج العربي التي تعيش بيئة تحديات مناخية ومتطلبات أقل للانتشار الواسع لمناطق التغذية. تقترح نقاط التحقق الأرضي بأن هذه المناطق قد تكون محدود لأماكن صغيرة تتواجد بها شعاب مرجانية متفرقة وببعد مئات الأمتار عن بعضها البعض. لقد تم توزيع مناطق التغذية في الركن الجنوب الغربي من الخليج العربي لقرابة 20،000 كيلومتر مربع بين إمارة أبوظبي في دولة الإمارات العربية المتحدة، وقسم صغير من المياه الإقليمية في السعودية، القسم الجنوبي باتجاه قطر. تم توزيع مناطق التغذية في عمان على أقل من 500 كيلو من الشريط الساحلي، ولكن هنالك منحدرات حادة للمياه العميقة قريبة من الساحل العماني، وتم حد موائلها للشرط الساحلي الضيق.

على عكس ما كانت توقعتنا في البداية بأن سلاحف منقار الصقر في الخليج العربي تفضل المناطق ذات الانحدارات الحادة نظراً لكونها وقدرتها لتأمين مستوى من الحماية، بدى الانتشار الواسع المبدد لهذه السلاحف على جنوب غرب الخليج قد يحد من الخيارات المتوفرة لحماية الموائل. تقع غالبية موائل التغذية لسلاحف منقار الصقر في مناطق المياه الضحلة المتداخلة مع مناطق الشحنٍ التجارية والتي لا تعتبر قضية رئيسية، ولكن تشهد هذه المناطق غالبية فعاليات الصيد. هنالك أيضاً مشاريع التطوير العمراني والصناعي في مناطق المياه الضحلة التي تقلص مناطق التغذية لسلاحف منقار الصقر. يجب تقييم فعاليات الصيد وتأثيرها على سلاحف منقار الصقر، مع النظر في تقديم أنظمة وبرامجٍ محافظة تضمن بقاء هذه السلاحف. لقد كان تعريف المناطق المهمة للسلاحف في عمان أكثر وضوحاً مع تعريف شاناه والقرية كمناطق تغذية رئيسية، ومياه رأس الحد، وبالطبع الشريط الساحلي بطول 20 كيلومتر بين جزر الديمانيات ومدينة مسقط وجزيرة مصيرة، والتي تعني مجتمعة مناطق مهمة للحفاظ على سلاحف منقار الصقر.

لدى قطاع الصيد الصغير الحجم مقومات لوضع تأثيرات سلبية على السلاحف البحرية. لقد كشفت هذه الدراسة للتعقب عبر الأقمار الاصطناعية عن وفاة سلحفاتان من أصل 90 سلحفاة، مما يعني بأن الوفاة الناجمة من فعاليات الصيد هي قضية اهتمام في المحافظة على السلاحف في المنطقة. من المهم الأخذ بالاعتبار الانتشار المبدد لسلاحف منقار الصقر والسلاحف الأخرى في المنطقة، وأن جهود الحفاظ على هذه السلاحف يجب أن تحظى بمساعدة مقاسات إدارة الصيد، والنظر بأهمية على تأثيرات قطاع الصيد على المستوى الإقليمي بشكل جدي.

يمكن استخدام نتائج أعمالنا من قبل الجهات الحكومية وهيئات الحفاظ على الطبيعة بأنماط تتماشى مع أنظمة المعلومات العالمية للتمكن من تقييم المخاطر على السلاحف البحرية في مواجهة التطور العمراني والصناعي، ويشمل ذلك قطاع النفط والغاز والصناعة، والتغير المناخي، وضغوط قطاع الصيد وفعاليات الشحن. سيعطي تقييم المخاطر مزيداً من الضوء على التداخل بين الموائل الهمامة للسلاحف والمخاطر الأخرى المختلفة في المنطقة العربية وتمهيد الطريق لوضع أهمية الأولويات للمناطق المهمة للسلاحف وتحديد خطة العمل والإدارة لحمايتها.

خلاصه اجرایی

مقدمه

منطقه‌ی عربستان که در این مطالعه شرح داده شده شامل خلیج فارس (که در این متن خلیج نامیده می‌شود)، در کنار خلیج عمان و دریای عرب است. این ناحیه از جمعیت بزرگی از لاکپشت‌های سبز در جزایر کاران و جانا در عربستان سعودی، و راس‌الجنز و راس‌الحد در عمان پشتیبانی می‌کند. در ایران و کویت تجمعات کوچکتری از لانه‌ها یافت می‌شود و اخیرا در امارات متحده‌ی عربی یک لانه پیدا شده است. زادگاه‌های پر تجمعی از لانه‌های لاکپشت‌های منقاردار در عربستان سعودی، ایران، کویت، قطر، عمان و امارات متحده عربی وجود دارد. جزیره‌ی مصیره در عمان یکی از بزرگترین زادگاه‌های لاکپشت‌های دریایی در جهان را دارا می‌باشد که لانه‌ی هزاران ماده به همراه لاکپشت‌های منقاردار و جمعیت کوچکی از لاکپشت‌های ریدلی زیتونی می‌باشد (ریس و همکاران، ۲۰۱۲ الف). با این حال، تا زمان انجام این مطالعه، بجز محل چند سایت لانه‌گزینی و استنتاجاتی مبنی بر اسفنج‌خواری لاکپشت‌های منقاردار که دال بر این بود که زیستگاه آنها صخره‌های مرجانی می‌باشد، هیچ اطلاع دقیقی از زیستگاه دریایی لاکپشت‌های منقاردار وجود نداشت.

خلیج، محیط منحصر به فردی است که دچار نوسانات شدیدی در دمای آب و هوا می‌شود. به همین دلیل، آب و هوای خلیج تاثیر عمیقی بر توسعه و توزیع گونه‌های دریایی می‌گذارد. دمای آب‌های سطحی معمولا برای دوره‌های پایداری از ۳۰ درجه سانتی‌گراد می‌گذرد و بدین ترتیب خلیج را می‌توان به آزمایشگاهی طبیعی زنده‌ای برای درک رفتار تنظیم حرارتی گونه‌های دریایی در برابر تغییرات آب و هوایی و افزایش دمای زمین تشبیه کرد. (تغیرات) دما مهم هستند، چراکه لاکپشت‌های دریایی خونسرد هستند و دمای داخلی بدن خود را از طریق پاسخ‌های رفتاری به تغییرات دما تنظیم می‌کنند. اثرات منفی تغییرات آب و هوایی شامل در دسترس بودن زیستگاه، موفقیت در لانه‌گزینی، زمان و دوره لانه‌گزینی، موفقیت به ثمر نشینی تخم‌ها، نسبت‌های جنسی، و سلامت نوزاد و غیره است. بنابر این توانایی لاکپشت‌ها (و دیگر گونه‌ها) در پاسخ‌گویی به تغییرات دمایی در زمانی که دمای جهان در حال افزایش است از اهمیت بیشتری برخوردار است.

لاکپشت‌های دریایی، به عنوان مصرف کننده و طعمه (دیگر گونه‌ها) نقش مهمی در بوم‌شناسی ایفا می‌کنند و به طور غیر مستقیم به ثبات بستر دریا و شیلات در ارتباطند. لاکپشت‌های دریایی می‌توانند به عنوان گونه‌ای شاخص از سلامتی نسبی زیستگاه‌هایی باشند که پشتیبان ماهی‌های تجاری و بی‌مهرگانی هستند که برای انسان ارزشمندند، و در بسترهای علف‌دریایی و اقیانوس‌ها و صخره‌های مرجانی و غیره یافت می‌گردند.

لاکپشت‌های دریایی در ناحیه‌ی عربی به طور سنتی به عنوان منبعی از گوشت و تخم استفاده شده‌اند. اخیرا صید لاکپشت‌های بالغ کمتر رایج است گرچه هنوز هم اتفاق می‌افتد و به نظر می‌رسد که صید تخم لاکپشت‌ها در جزایر دور دست در حال افزایش است. به علاوه بسیاری از لاکپشت‌های کوچک‌تر در سواحل خلیج به دلیل خیرگی از سرما در ماه‌های زمستانی و تعداد فزاینده‌ای از لاکپشت‌های بزرگتر با علایم خفگی ناشی از گیرافتادن در وسایل ماهیگیری می‌میرند. همچنین خلیج فارس یکی از مهمترین مراکز کشف و استخراج نفت‌وگاز جهان است و هر دوی خلیج فارس و دریای عمان یکی از پر تراکم‌ترین نواحی کشتیرانی جهان از طریق تنگه هرمز هستند که این امر به طور جدی لاکپشت‌ها را تهدید می‌کند. به علاوه‌ی تمام این‌ها، ماهیگیری صنعتی و سنتی در تمام کشور ها، لاکپشت‌ها را به شکل مضاعفی تحت تاثیر قرار می‌دهد. ساخت و سازهای ساحلی هم عامل دیگری است که با تخریب ساحل‌های لانه‌گزینی و صخره‌هایی که محل تغذیه لاکپشت‌ها است و علف‌های دریایی، تمام مراحل زندگی لاکپشت‌ها را در خلیج تهدید می‌کند. به علاوه ساخت و سازهای ساحلی، سر و صدا، نور و آلودگی‌های فیزیکی می‌تواند رفتارهای مهاجرتی و لانه‌گزینی لاکپشت‌ها را تحت تاثیر قرار دهد. با توجه به این فشارها، نیاز قابل ملاحظه‌ای برای استراتژی‌ها متمرکزی که طیف کامل و گسترده‌ای از زندگی لاکپشت‌ها را هدف قرار می‌دهد، وجود دارد.

اطلاعات ردیابی ماهواره‌ای از ۹۰ لاکپشت منقاردار ماده (۷۵ لاکپشت توسط این پروژه و ۱۵ لاکپشت توسط گروه‌های همکار) پس از لانه‌گزینی، از نواحی لانه‌گزینی در ایران، عمان، قطر و امارات متحده عربی برای

تعشيش. تشير النتائج العامة بأن سلاحف منقار الصقر في المنطقة العربية لها قدرة على التعشيش ست مرات في الموسم) حدث التعشيش الذي شاهده فريق العمل وخمسة أحداث إضافي(، ولكن يمكن القول بأن معدل التعشيش قد يكون قرابة ثلاث مرات في الموسم، مع فعاليات تعشيش أقل من غالبية أعداد السلاحف في عمان والخليج العربي.

لقد توجهت السلاحف في الخليج العربي بشكل رئيسي باتجاه الجنوب أو الجنوب الغربي نحو الزاوية في الجنوب الغربي للخليج العربي التي تشارك بها دولة الإمارات العربية المتحدة السعودية وقطر، هنالك من نسبة صغيرة من السلاحف التي توجهت داخل خليج سلوى)بين قطر والسعودية(والشمال الشرقي باتجاه البحرين، السعودية والكويت. توجهت السلاحف من جزر الديمانيات باتجاه الشمال الشرقي لساحل عمان، وحول راس الحد متجهة نحو الشمال الشرقي لمواقع التغذية القريبة من الساحال الرئيسي بالقرب من جزيرة مصيرة وباتجاه سواحل اليمن. لقد كان توجه السلاحف من جزيرة مصيرة نادراً ليكون أكثر من 50–80 كيلومتر للمناطق التغذية الساحلية لسلطنة عمان، باستثناء سلحفاة واحدة قطعت مسافة 350 كيلومتر باتجاه الشمال الغربي.

لقد كان مسار هجرة سلاحف الخليج العربي قصير وتم اتمامه ضمن معدل فترة بلغت 10.3 يوماً ومسافة وصلت إلى 189.4 كيلومتر. وكان مسار هجرة السلاحف من جزر الديمانيات الأطول وبمعدل بلغ 672.6 كيلو متر ومعدل 28.6 يوم. تمكنت جميع السلاحف باستثناء سلحفاتان من الوصول إلى أو المرور بجيزة مصيرة الكائنة على السحل الجنوبي في سلطنة عمان، وقامت سلحفاة بالهجرة باتجاه الخليج العربي عبر مضيق هرمز، وهو أول مرة يتم بها رسمياً تسجيل هذه الحادثة. وعلى عكس ذلك، لوحظ بأن السلاحف التي تم تعقبها في جزيرة مصيرة كان مسار هجرتها هو الأقصر بمعدل بلغ 80.5 كيلوامتر ومعدل 3.95 يوم. وعلى نطاق سرعات السفر التي استغرقت السلاحف في هجرتها لم يتم ملاحظة فروق ملحوظة بين سلاحف الخليج العربي وسلاحف جزيرة مصيرة أو الديمانيات، وكان معدل السرعة والمسافة اليومية خلال الهجرة 19.02 كيلومتر في اليوم.

لوحظ بأن السلاحف التي اتبعت مسار الهجرة الصيفية قامت بمسار دائري مغلق باتجاه الشمال الشرقي نحو أعماق الخليج العربي بين شهر يوليو وأغسطس، والعودة باتجاه الجنوب الغربي نحو المياه الضحلة ومناطق التغذية في شهر سبتمبر وأكتوبر. هنالك سرعة سفر أعلى وملحوظة خلال هذا المسار الصيفي المغلق للهجرة مقارنة بسرعات الهجرة السابقة، أو توجهها نحو مناطق التغذية بمعدل سرعة بلغ 4.6 كيلومتر في اليوم، ومسار هجرة صيفية بمعدل 10.9 كيلومتر في اليوم. لقد اشتق مصطلح مسار الهجرة الصيفية المغلق من التوقيت العام للتغير في التصرف مع مغادرة السلاحف المياه الدافئة وتوجهها نحو مياه بدرجة حرارة أقل بدرجتين، وعدم العودة لغاية انخفاض درجة حرارة المياه بشكل ملحوظ في الجزء الجنوب الغربي من الخليج العربي.

تحتل السلاحف في الخليج العربي مناطق معينة ومناطق تغذية منعزلة، وتعود عادة لنفس المناطق خلال هجرتها الصفية التي تمتد من شهرين لثلاث أشهر، وتتحرك بشكل متكرر نحو مناطق جديدة. لم يلاحظ توجه أي من السلاحف بالاتجاه شرقاً نحو إيران باستثناء سلحفاة واحدة، وتقصد السواحل الشرقية في دولة الإمارات العربية المتحدة التي تتميز بعلو نظافة مياها الداخلة للخليج العربي من خليج عمان. لوحظ بأن السلاحف من جزر الديمانيات وجزيرة مصيرة من عمان تهاجر بشكل رئيسي نحو مياه شناص القريبة من سواحل مصيرة، وتوجه بضعة منها نحو قرية التي تبعد مسافة 250–300 كيلومتر.

سرعة السفر كانت أبطئ عند قضاء فترة التغذي (=4.5 km/day) مقارنة مع فترة الهجرة (19.02 كيلومتر في اليوم) أو المسارات المغلقة (10.9 كيلومتر في اليوم). وعلى نطاق المجال، تفاوت المجال ولكنه كان صغيراً بشكل عام وبمعدل 48.7 كيلومتر مربع. لقد كان المجال في غالبية الحالات بين 40 و 60 كيلومتر مربع. وعلى عكس ذلك، كانت المناطق المحورية دقيقة جداً، ومحدودة لمناطق وبقع ضحلة منفردة بمعدل 3.3 كيلومتر مربع، وغالبيتها بمقاس 3 إلى 5 كيلومتر مربع. بلغ معدل مساحة المجال لسلاحف الخليج الربي 52.4 كيلومتر مربع وكان أكبر لمجال السلاحف خارج الخليج العربي (=39.7 km^2). عكست المناطق المحورية هذا النمط الذي يعتقد بوجود مناطق تغذية أفضل قبالة المحيط الهندي مقارنة مع الخليج العربي الذي يواجه تحديات قاسية من التغير المناخي.

لقد وفرت سلحفاتان معلومات عن نقاط الصيد: الأولى في سلحفاة تم تعقبها من جزر الديمانيات توجهت شمال شرق نحو رأس الحد. قامت هذه السلحفاة بعد ذلك بعكس مساراها بعد انعطافها والاتجاه شمال شرق عابرة خليج عمان. تم تحليل إشارات التعقب التي أشارات إلى قوة الإشارات الواردة وكانت جميعها تشير إلى مواقع في الأراضي اليابسة مما يشير إلى أن السلحفاة كانت على سطح قارب صيد، وانتهت الإشارات في منتصف الطريق بين عمان والباكستان. السلحفاة الثانية تركت منطقة التغذية في منتصف

الخليج العربي واتجهت بشكل مفاجئ نحو الشمال الشرقي باتجاه إيران. وتم عند تحليل إشارات التعقب على مدى ستة شهور بأنها على الأراضي اليابسة في منطقة قريبة من كوشنوكار في إيران.

المناقشة

من المعتقد بأن صغر حجم جسم السلاحف البحرية في الخليج العربي له علاقة بدرجات الحرارة المرتفعة، حيث تتراوح درجات حرارة سطح البحر من 16 درجة مئوية كحد أدنى في أشهر الشتاء، إلى 37 درجة مئوية كحد أقصى في أشهر الصيف. التعرض لدرجات حرارة تتجاوز معدل التحمل الطبيعي قد يؤدي إلى انخفاض في امتصاص الغذاء والنمو، وتؤدي درجات حرارة أشهر الشتاء الباردة إلى تشتت العديد من صغار السلاحف. تُعد أحجام سلاحف الخليج العربي البالغة ضمن أصغر أحجام السلاحف الكبيرة في العالم، ويعتقد بأن نموها وتغذيتها محدودة.

يمكن لمجموع معلومات التوالد على النطاق الإقليمي أن توفر معرفة عن متانة أعداد السلاحف، وتتيح لجهات الادارة والحفاظ تتبع أداء الأعداد عبر الزمن. تفسير هذه البيانات يساهم في التقييم الدقيق لتكرار التعشيش. لقد وضحت هذه الدراسة بأن السلاحف من عمان قامت بوضع البيض لمرات أقل مقارنة مع السلاحف من الخليج العربي، وبناءً على فترات الاحتفاظ في أماكن التعشيش المتداخلة بعد وضع جهاز التعقب يمكننا التقدير بأن السلاحف لها قدرة على وضع البيض لغاية خمس مرات (وفي بعض الأحيان ست مرات)، ولكن كان الوضع الطبيعي لها بوضع البيض ثلاثة مرات في الموسم.

لا تعبر أنماط دوران المياه في الخليج العربية قوية حيث يبلغ معدلها 0.1 كيلومتر في الساعة، ونعتقد بأنها ذات مكانة قليلة لهجرات ما بعد التعشيش للسلاحف ضمن الخليج العربي. ويبدو بأن حجم الجسم الصغير لسلاحف منقار الصقر في الخليج العربي له تأثير بسيط لقدرها على السباحة. لقد كان معدل المسافات التي تم قطعها في الخليج العربي خلال الهجرة أقل نسبياً من المعدلات العالمية، والتي تعكس صغر حجم الجسم وغياب الهجرة لخليج عمان وإلى أبعد من ذلك. لوحظ بأن السلاحف الكبيرة في الخليج العربي من الجزء الشرقي توجهت نحو الجنوب الغربي، والجنوب متجهة عكس التيارات في وسط الخليج. ولوحظ بأن السلاحف من شمال قطر قامت بالهجرة جنوباً، وجنوب شرق متجهة مع مسار التيارات المحلية، وتوجه عدد كبير منها نحو الشمال، والشمال الغربي من مناطق التعشيش. وقيام ثلاث سلاحف دخول خليج سلوى، والهجرة بين قطر والبحرين وللخارج مجدداً.

يبدو بأن التيار البحري الصومالي في بحر العرب لم يكن عارضاً قوياً للسباحة التي تم تسجيلها لسلاحف عمان مع العلم بأن سلاحف منقار الصقر تقضي أوقات جلوس أكثر مقارنة مع انواع السلاحف البحرية الأخرى. لقد كانت مسافات الهجرة للسلاحف المغادرة لجزر الديمانيات أكثر بمرتين من المعدل العالمي لسلاحف منقار الصقر مع أقصى مسافة هجرة بلغت قرابة 1100 كيلومتر. لقد غطت السلاحف المغادرة لجزيرة مصيرة مسافة أقل من المعدلات العالمية، حيث بلغت مسافة هجرتها 80.5 كيلومتر فقط. لكن واحدة من هذه السلاحف توجهت قرب الأراضي العمانية الرئيسية بمعدل مسافة أكثر من 30 كيلومتر، وهي أقل بكثير من المعدل العالمي الذي يبلغ 327 كيلومتر. يمكننا القول بأن نقطة الازدحام في منطقة رأس الحد هي موضع اهتمام للسلاحف العمانية مع العلم بوجود فعاليا صيد كثيرة في هذه المنطقة. قامت جميع السلاحف من جزر الديمانيات باستثناء سلحفاة واحدة التوجه والالتفاف حول رأس الحد، ومن ثم توجهت جنوب غرب نحو جزيرة مصيرة وأبعد من ذلك، ونقترح بأن يتم اعتبار هذه المنطقة مهمة جداً كمسار للسلاحف في المنطقة. وكان الحال مماثلاً في عمان ونقترح بأن تكون المنطقة بين الجزء الجنوبي من جزيرة مصيرة وشناص القريبة من الأراضي الرئيسية لتكون منطقة مسار مهمة لهجرة السلاحف ومناطق للتغذية.

تشير نتائجنا إلى أن سلاحف منقار الصقر في الخليج العربي تقوم بتطبيق نظام تجاوب مع التغيرات الحرارية التي تأخذها بعيداً عن درجات الحرارة المرتفعة، ومقومات فيزيولوجية لظروف المخاطر. تصل درجة حرارة سطح البحر في فصل الصيف لمعدل 33.5 درجة مئوية وترتفع لغاية 34.9 درجة مئوية. يتم خلال هذه الفترات الطويلة لارتفاع درجات الحرارة (يونيو–أغسطس) هجرة السلاحف بمعدل مسافة 70 كيلومتر نحو المياه العميقة والأبرد تجاه الشمال، والعودة بعد 2–3 أشهر (سبتمبر–أكتوبر) لمناطق التغذية الرئيسية. تباين درجات الحرارة ($t\Delta$) بين مناطق التغذية وموائل الدورة الصيفية تحركت باتجاه الشمال الشرقي نحو المياه العميقة، والعودة باتجاه الجنوب الغربي للمياه الأقل عمقاً ومناطق التغذية. لقد كانت سرعة السباحة أسرع بشكل ملحوظ وكان الاتجاه أكثر وضوحاً خلال هذه الهجرات مقارنة مع هجراتها لمناطق التغذية. وكانت هجرات الخروج ذات ترابط عكسي مع درجات الحرارة، ولكنها لم تكن مرتبطة مع

الملخص التنفيذي

المقدمة

تشمل المنطقة العربية الوارد شرحها في هذه الدراسة كل من الخليج العربي، وخليج عمان وبحر العرب. تدعم المناطق المتواجدة في هذه البحار أعداد السلاحف الخضراء في كل من جزيرة كران وجانا في المملكة العربية السعودية، وراس الجينز وراس الحد في سلطنة عمان. هنالك أيضا مناطق تعشيش أخرى صغيرة في دولة الكويت وإيران، وتم مؤخراً العثور على مناطق تعشيش في دولة الإمارات العربية المتحدة. كما يوجد ايضا مناطق تعشيش لسلحفاة منقار الصقر في كل من المملكة العربية السعودية، إيران، الكويت، قطر، سلطنة عمان ودولة الإمارات العربية المتحدة. ويجدر الذكر هنا بأن جزيرة مصيرة في عمان تعد الموطن الأكبر في العالم لتعشيش السلاحف الضخمة الرأس، حيث تتوافد آلاف من الإناث لوضع البيض، بجانب سلاحف منقار الصقر وسلاحف أوليف ريدلي التي تأتي بأعداد قليلة (المصدر Rees *et al.* 2012a). لم يكن هنالك ولغاية بداية هذه الدراسة لدينا معلومات كافية عن موائل سلاحف منقار الصقر باستثناء مواقع تعشيشها، والمداخلات المستنتجة من نظام غذائها الذي اعتقد بأنه ينحصر على وجودها في مناطق وموائل الشعاب المرجانية.

يتميز الخليج العربي ببيئة فريدة من نوعها تخضع لتغيرات قاسية في درجات حرارة الماء والهواء، والتي نتج عنها تأثير قوي على تطوير الكائنات البحرية وتوزيعها. تتخطى درجة حرارة سطح البحر عادة 30 درجة مئوية لفترات طويلة، ويمكن من هنا ربط الخليج العربي بكونه مختبر حي على أرض الواقع للتعرف على نمط تصرف الأحياء البحرية مع هذه التغيرات في درجات الحرارة ومواجهاتها للتغير المناخي وظاهرة ارتفاع درجات الحرارة على النطاق العالمي. تُعد درجة الحرارة مهمة جدا للسلاحف البحرية نظراً لأنها من فصيلة كائنات الدم الحار التي تتحكم بدرجة الحرارة الداخلية في أجسامها من خلال التجاوب والتصرف مع تغيرات درجات الحرارة. لا يقتصر هذا التغير على السلاحف فقط، بل يمتد ليشمل تأثيرات سلبية على وفرة الموائل ونجاح التعشيش، ووقت التعشيش وفتراتها ونجاح فترة حضانة البيض ونسبة الذكور والإناث، والعديد من العوامل الأخرى. يعني كل ذلك بأن قدرة السلاحف البحرية (والكائنات البحرية الأخرى) على التجاوب مع تغيرات درجات الحرارة قد يصبح أمراً ذو علاقة أكثر في مواجهة ظاهرة ارتفاع درجات الحرارة العالمية.

تلعب السلاحف البحرية دوراً بيئياً قيماً نظراً لأنها تعتبر مستهلكاً ومفترساً وذات صلة غير مباشرة لقاع البحر وثبات الثروة السمكية. ويمكن القول بأن السلاحف البحرية هي مؤشر لصحة الموائل التي تدعم قطاع الصيد التجاري واللافقاريات التي تتواجد موائل الأعشاب البحرية، والمحيطات المفتوحة ومناطق الشعاب المرجانية التي بها مكانة قيمة عند الإنسان. إضافة لذلك، لدى السلاحف البحرية مكانة هامة وغنية في قطاع السياحة، والتعليم والأبحاث.

لقد كانت السلاحف البحرية في المنطقة العربية منذ القدم مورداً تقليدياً للحم والبيض. ولكن أدى عزوف العديد عن هذه الممارسات إلى تراجع ملموس في صيد كبار السلاحف، ولكن يبدو بأن أنشطة جمع بيض السلاحف في الجزر النائية في زيادة مستمرة. إضافة لذلك، هنالك العديد من صغار السلاحف متشتتة على شواطئ الخليج نتيجة البرد القاسي في الشتاء، وتشتت العديد من السلاحف البالغة ونفوق الكثير منها نتيجة الاختناق في شباك الصيد. تزدهر منطقة الخليج بكونها من أهم المناطق في العالم لحقول النفط والغاز الطبيعي، ويشهد الخليج العربي وخليج عمان مكانة تجعلهما من أكبر مسارات ووجهات الشحن البحري في العالم التي تمر عبر مضيق هرمز مما يزيد من عوامل الخطر على السلاحف. أضف لك ذلك أنشطة الصيد التجارية والترفيهية في جميع الدول المطلة على الخليج والتي تزيد بدورها التأثير على السلاحف البحرية. هنالك أيضاً التطوير الساحلي الذي يعد من عوامل الخطر الرئيسية في جميع مراحل دورة حياة السلاحف في الخليج العربي، منها على سبيل المثال خسارة شواطئ التعشيش وموائل الشعاب المرجانية للتغذية، وخسارة موائل الأعشاب البحرية نظراً لعمليات الحفر والردم. أضف لذلك إجراء التعديلات على المناطق الساحلية والضوضاء والإضاءة والتلوث الذي له تأثير على مسار هجرة

السلاحف وأنماط تعشيشها. تأتي هذه الضغوط مجتمعة لتجعلنا نأخذ بعين الاعتبار ضرورة التركيز في وضع إستراتيجيات الحفاظ التي تستهدف جميع المخاطر وسبل الحفاظ على دورة حياة طبيعية للسلاحف البحرية.

لقد تمكن المشروع استخدام تقنية التعقب عبر الأقمار الاصطناعية لتعقب 90 أنثى من سلحفاة منقار الصقر بعد وضعها للبيض (تعقب 75 من قبل المشروع، و15 من قبل الشركاء) في مواقع تعشيش في عمان، قطر، دولة الإمارات العربية المتحدة وإيران، واستخدام دولة الإمارات العربية المتحدة لتعريف الموائل الرئيسية للغذاء، وأنماط الفعاليات المختلفة وأماكن التقاء مسارات الهجرة. من المتوقع أن تساهم هذه المعلومات والتحاليل في تحسين المعرفة العامة عن سلاحف منقار الصقر وتصرفها مع بيئة مليئة بالتحديات، والمساهمة أيضاً في معرفتنا للمناطق المهمة للسلاحف في المنطقة العربية، ودعم جهود سياسات واتخاذ القرارات للحفاظ على السلاحف البحرية على المستويات الوطنية والإقليمية.

الطرق

لقد تم استخدام أجهزة التعقب عبر الاقمار الاصطناعية ووضع الجهاز على ظهر السلحفاة باستخدام طريقة التثبيت بواسطة الصمغ وشرائح الألياف الزجاجية. تم أخذ مقاسات جميع السلاحف التي تم تعقبها، وأخذ عينة للتعرف على بياناتها الجينية. وأشارت نتائج تحليل المعلومات إلى أن السرعة الثابتة للسلاحف كانت ≥ 5 كلم في الساعة، ولم يشمل ذلك البيانات غير الواقعية، مثل نقاط التثبيت الأرضية، وأماكن آلاف الكيلومترات من نقاط التأكد السابقة. لقد اخترنا نقطة ثابتة واحدة لكل سلحفاة في اليوم، وذلك من خلال اختيار أعلى وأدق نقطة تثبيت. وفي حال وجود أكثر من إشارة واحدة عالية الجودة، قمنا باختيار النقطة الأقرب لمنتصف اليوم. لقد قمنا بتصنيف جميع النقاط الواردة قبل مغادرة موقع التعشيش في فئة النقاط ذات موضع اهتمام. وتم لكل مجموعة من النقاط على مدى اسبوعين خلال التصرف المهم اعتبارها محدث ناتج بعد حدث وضع البيض. وتم تصنيف زيادة سرعة السفر والافتراض بالسفر دون تحديد الاتجاه لغاية بداية التغذية في فئة مسارات الهجرة. تم أيضاً التعرف على مناطق التغذية عن طريق تقليل معدلات السفر والتغير من التوجه المقصود، الاتجاهات غير المنتظمة للتحركات في مسافات قصيرة مع تغيرات عشوائية في الاتجاهات. تم تسجيل توجهات مقصودة باتجاه وسط الخليج العربي من شهر يوليو إلى أغسطس، تلاها عودة في شهر سبتمبر إلى أكتوبر، وتم تصنيف هذه التوجهات على أنها مسارات الهجرة الصيفية. لقد قمنا بحساب منطقة المجال (50% كثافة مناطق التغذية) ومناطق محورية (50% من مواقع التغذية) لشرح الامتداد المحيطي لمناطق التغذية الانفرادية وللتعرف على أهم المناطق للسلاحف (ITAs).

لقد قمنا أيضاً باستخدام بيانات التحسس الفيزيائية والحيوية عن بعد لشرح البيئة البحرية لموائل التغذية وخلال فترات الهجرة: شمل درجة حرارة سطح البحر (SST)، ارتفاع سطح البحر (SSH) وتيارات حركة الأرض، وكثافة الكلوروفيل السطحية. قمنا باستخلاص البيئة المعنية والبيانات الحيوية ذات صلة بموقع كل سلحفاة في محيط البحث (المحرفة محيطياً بين نقاط الشبكة ونقاوة مماثلة للتغيرات البيئية المنفردة) والوقت، والتأكد من العلاقات بين هذه التغيرات ونقاط مواقع السلاحف وحالة التصرف، مع أوقات تغيرات التصرفات لشرح التجاوب مع التصرفات.

النتائج

وجود الفارق في أنماط الهجرة والتصرفات للسلاحف التي تم تعريفها في الخليج العربي، وجزيرة مصيرة وجزيرة الديمانيات، أخذت أعمال التحاليل التي قمنا بها لهذه المجموعات بشكل منفرد. وتبين لنا وجود فارق ملحوظ في درجة الانحناء للدرع والطول بين سلاحف الخليج العربي وخليج عمان. كان معدل مقاس درع السلاحف في الخليج العربي 70.3 سم (CCL)، بينما كان أكثر بـ 10 سم في سلاحف خليج عمان بمعدل طول بلغ 81.4 سم للدرع.

لقد كان معدل الفترة الزمنية بعد وضع جهاز التعقب وقبل بداية الهجرة عند بعض السلاحف في الخليج العربي 20.1 يوم والذي يمثل معدل 1.4 دورة تعشيش مع احتمال مجال 0–5 أحداث تعشيش. لم يكن هنالك فارق ملحوظ في فعالية التعشيش من قبل السلاحف من جزر الديمانيات أو مصيرة، وكان المعدل المدمج لفترة التعشيش من عمان 11.1 يوم، وهو يمثل معدل 0.9 دورة تعشيش مع احتمال مجال 0–3 حدث

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نحوه رجوع پیشنهادی

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Final Scientific Report. EWS-WWF, Abu Dhabi, UAE

تهیه شده تحت قرارداد با

انجمن حیات وحش امارات – WWF
امارات متحده عربی، ابوظبی، صندوق پستی ۴۵۵۵۳.

نبذة عن جمعية الإمارات للحياة الفطرية (EWS-WWF)

إن جمعية الإمارات للحياة الفطرية (EWS-WWF) هي منظمة إماراتية بيئية غير حكومية، أنشئت برعاية صاحب السمو الشيخ حمدان بن زايد آل نهيان، ممثل الحاكم في المنطقة الغربية ورئيس مجلس إدارة هيئة البيئة – أبوظبي. منذ تأسيسها في عام 2001، تعمل جمعية الإمارات للحياة الفطرية (EWS-WWF)، أحدى أكبر المنظمات البيئية المستقلة في العالم، وتهدف إلى خفض البصمة البيئية ومكافحة تغير المناخ والحفاظ على التنوع البيولوجي في الإمارات والمنطقة. تعمل الجمعية على المستوى الاتحادي تحت لرئاسة مجلس إدارة محلي ولها عدة مكانب في أبوظبي ودبي و الفجيرة.

نبذة عن صندوق الأبحاث البحرية (MRF)

صندوق الأبحاث البحرية هو صندوق أبحاث لا يهدف للربح تأسس في مدينة كوتا كيناباولو في ماليزيا وفقاً لأمناء ماليزيا لعام 1951. هدف تأسيس الصندوق يكمن في تعزيز المعرفة عن التنوع الإحيائي في البيئة البحرية وعلاقة هذا التنوع بالحياة الفطرية في جنوب شرق آسيا ومناطق الباسيفيك الهندية الأخرى. يقوم الصندوق بعدد من المشاريع ذات صلة بتقييم التنوع الإحيائي والحفاظ عليه، والسعي لتوفير حلول إدارية مناسبة للجهات الحكومية وهيئات الحفاظ على التنوع الإحيائي.

تنويه من جمعية الإمارات للحياة الفطرية (EWS-WWF)

إن تصنيف الهيئات الجغرافية في هذا التقرير وعرض المادة لا يعبر عن رأي جمعية الإمارات للحياة الفطرية (EWS-WWF) حول الوضع القانوني لأي بلد أو إقليم أو منطقة أو سلطاته، أو يتعلق برسم حدود لأقطاره أو حدوده.

الشركاء في المشروع | همکاران پروژه

حیات وحش امارات درباره جامعه (EWS-WWF)

جامعه حیات وحش اما ا رت (EWS) یک سازمان غیر دولتی (NGO) محیطزیستی اماراتی است که تحت حمایت شیخ حمدان ابن زیاد آل نهیان، نماینده حاکم در منطقه غربی و ریاست آژانس محیطزیست در ابوظبی، بنیان گذاری شده است.

EWS در ارتباط با WWF که یکی از بزرگترین و محترم‌ترین سازمان‌های مستقل حفاظت از محیط زیست است فعالیت می‌کند. EWS-WWF از سال ۲۰۰۱ میلادی در امارات به فعالیت پرداخته و پروژه‌های حفاظتی و آموزشی متعددی را در منطقه اجرا کرده است. EWS-WWF به صورت فدرال به فعالیت می‌پردازد و دفاتر آن در ابوظبی، دبی و فجیره توسط هیات مدیره محلی اداره می‌شود.

درباره بنیاد تحقیقات دریایی (MRF)

بنیاد تحقیقات دریایی یک بیناد تحقیقاتی غیرانتفاعی به مرکزیت کوتا کینابالو در مالزی و تحت قانون امنای ۱۹۵۱ مالزی است. این بنیاد به منظور ارتقای درک اکوسیستم دریایی در ارتباط با فلور و جانوران متنوع دریایی در ناحیه جنوب‌شرقی آسیا و هند و نواحی آسیایی اقیانوس آرام پایه گذاری شده است. بدین منظور این بنیاد پروژه‌های متعددی در ارتباط با ارزیابی تنوع زیستی و حفاظت از محیط زیست انجام می‌دهد و سعی می‌کند که راه‌حل‌هایی مدیریت‌گرا در اختیار ارگان‌های دولتی و حفاظتی قرار دهد.

محدوده مسولیت EWS-WWF

ذکر نهادهای جغرافیایی در متن این گزارش و در بیان محتوای آن آمده، به هیچ‌وجه بیانگر هیچ‌گونه نظری از EWS-WWF در ارتباط با وضعیت حقوقی، قلمرو، منطقه و مقامات هیچ کشوری، و یا در ارتباط با تعیین حدود سرحدات یا مرزهای آن کشور نمی‌باشد.

تم نشر هذا
التقرير بالاشتراك
مع MRF

مشروع الحفاظ على السلاحف البحرية
الموجز التنفيذي للتقرير العلمي النهائي

المنطقة العربية