Introduction

In 2016, the Kingdom of Saudi Arabia (KSA) commenced implementation of ambitious and far-reaching plans to diversify the national economy in line with the national strategy, Vision 2030. A key tenet of the national strategy is to substantially increase the volume of non-pilgrimage tourists travelling to KSA. The development of key destinations along KSA's Red Sea coastline was identified as a key driver that would allow for this objective to be realized. To facilitate this vision, The Red Sea Development Company (TRSDC), now Red Sea Global (RSG), was established in 2018 by KSA's Public Investment Fund (PIF), with a remit to develop The Red Sea tourism destination. The Red Sea aims to develop luxury tourism and residential facilities based predominantly around the archipelago of islands within a natural lagoon referred to as the Al Wajh Bank and beyond.

The Al Wajh Bank and the surrounding lagoon ecosystem is a particularly sensitive natural location with a high-quality marine environment. The lagoon, comprising 92 islands, supports regionally significant aggregations of nesting Hawksbill (*Eretmochelys imbricata*) and Green turtles (*Chelonia mydas*). In 2018, RSG undertook a Marine Spatial Planning (MSP) process (Chalastani, et al., 2020). Taking into account the outcomes of the MSP process, the Red Sea Concept Masterplan (CMP) has targeted development of seven of the largest islands in the lagoon and 24 of the smaller islands for development through a phased development approach. Phase 1 of the development is nearing completion, with the first project of The Red Sea opening to the public in 2023.

A Biodiversity Action Plan (BAP) developed for RSG has established a target of enhancing the population status to achieve net gain in absolute numbers ≥10% across past and present three-year averages, and to maintain the current genetic diversity of marine turtles in the project area. To help achieve this, RSG have initiated programmes to enhance understanding of the marine turtle distribution and population dynamics with a view to developing and implementing informed management and conservation strategies.

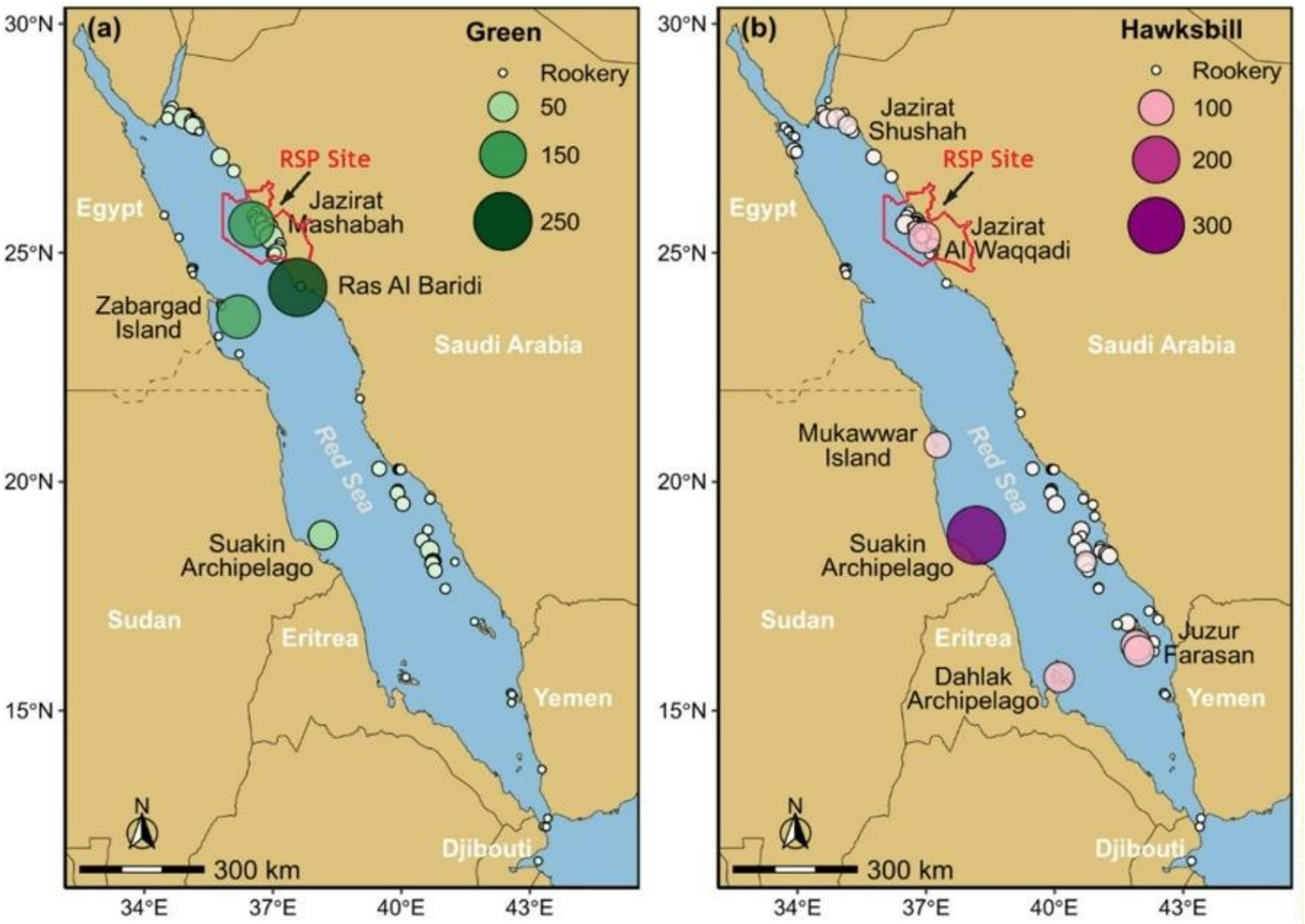
The initial MSP and CMP exercise was conducted soon after The Red Sea was initiated and while the understanding of the ecology of the Al Wajh lagoon was still developing. As the project has progressed and understanding of the system has improved, challenges with reconciling the needs of the development with conservation objectives have been identified. This paper aims to highlight the approaches that have been taken to embed conservation measures that safeguard turtle-nesting habitat into the planning process and mitigate these conflicts as they arise at the project level. There is a need to ensure that conservation and planning can be optimized through adaptive management approaches that are science-based and are reviewed and updated as the project progresses. This paper also identifies initiatives that can be applied by RSG at varying scales to further strengthen the planning efforts.

Turtle Breeding at the Red Sea

Of the five species of turtle recorded in the Red Sea, two are commonly recorded at The Red Sea project area. Hawksbill turtles are globally listed as critically endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, while the Green turtle is listed as endangered globally (Meylan & Donnelly, 1999; Miller, 2018; Seminoff, 2004; Seminoff & Shanker, 2008). The Red Sea is recognized as one of the most important zones within the Red Sea geographic region in terms of Green turtle and Hawksbill turtle nesting

distribution, abundance, and rookery size (Figure 1) (Al Ameri, et al., 2022; Shimada, et al., 2021).

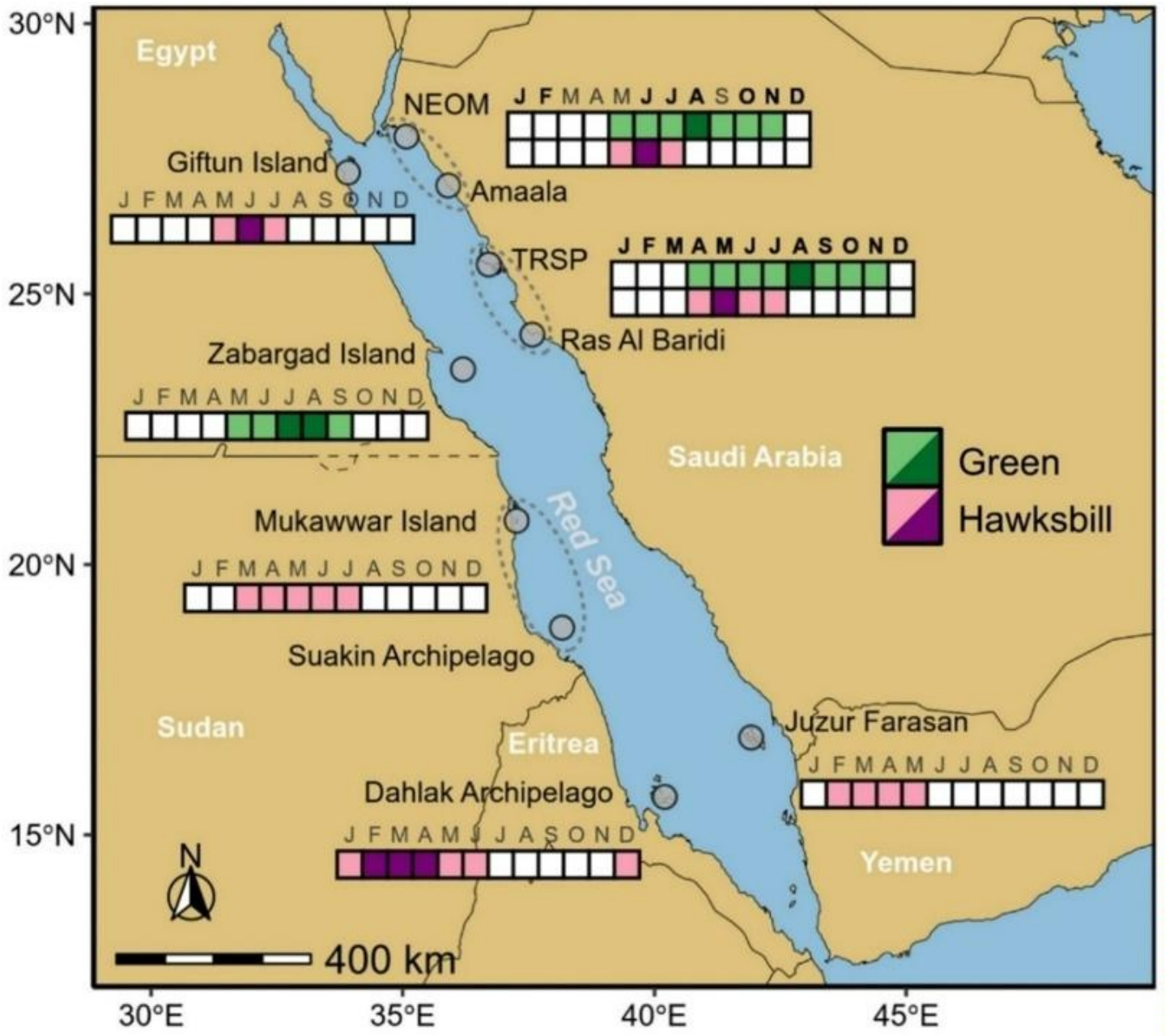
Figure 1 Distribution and Estimated Abundance of Nesting Green and Hawksbill Turtles in the Red Sea



Source: Adapted from Shimada et al. (2021)

The reproductive periods of both green and hawksbill turtles in the Red Sea are seasonal. In the northern Red Sea, Hawksbill turtles have traditionally been understood to breed and nest between April and July, with a peak in May. Green turtles have been recorded nesting between April and November, with peak activity in August (Figure 2) (Shimada, et al., 2021).

Figure 2 Nesting Season of Green and Hawksbill Turtles in the Red Sea (Shimada, et al., 2021)



Lighter colours indicate nesting activities in each month (shown by a capital letter above each box) with darker colours denoting the peak periods.

Source: Shimada et al. (2021)

Understanding of nesting seasonality continues to develop. In February 2024, RSG and KAUST field survey personnel identified female hawksbill turtles exhibiting nesting approach behaviour at two islands in The Red Sea. This is the earliest month for recorded evidence of nesting behaviour in the lagoon and suggests that there may be low levels of Hawksbill nesting activity in the Al Wajh lagoon throughout a larger proportion of the year than previously thought (Barrios-Garrido, H. *pers comm*).

A high proportion of the nesting recorded within the Red Sea area is focussed on specific islands. Shimada et al. (2021) found that approximately 61% of nesting events in 2018 and 2019 were on Breem Island, and the remaining nestings reported on 16 other islands (Figure 3). Hawksbill turtle nesting was more dispersed, with records from 2018 on 37 islands showing 43% of the nests on Al Waqqadi island (

Figure 4). Based on RSG survey data, there were an estimated 173 nesting female Greens and 69 nesting female Hawksbills in The Red Sea area in 2022 (RSG, 2023).

Figure 3 Main Green Turtle Nesting Sites in Red Sea

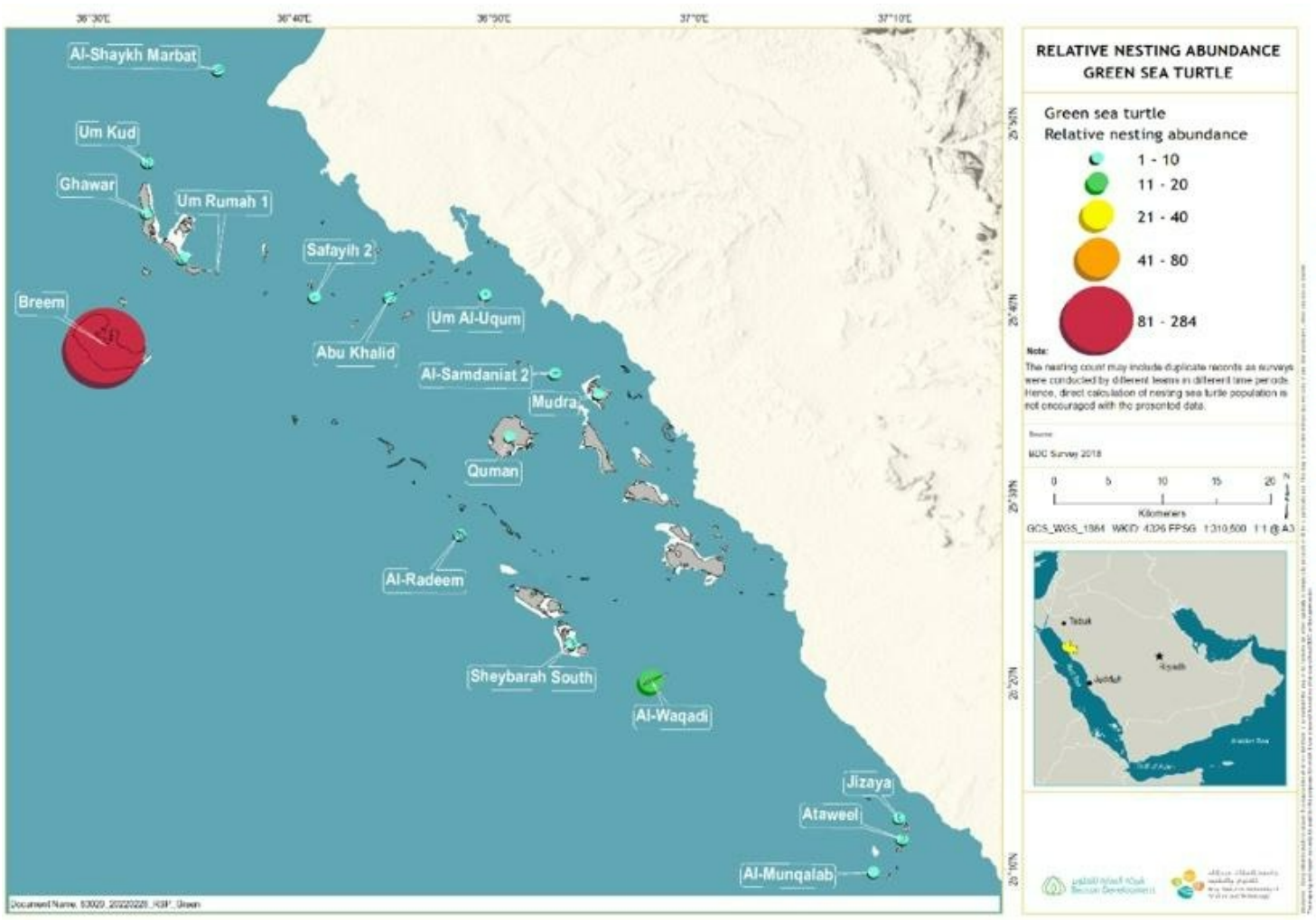
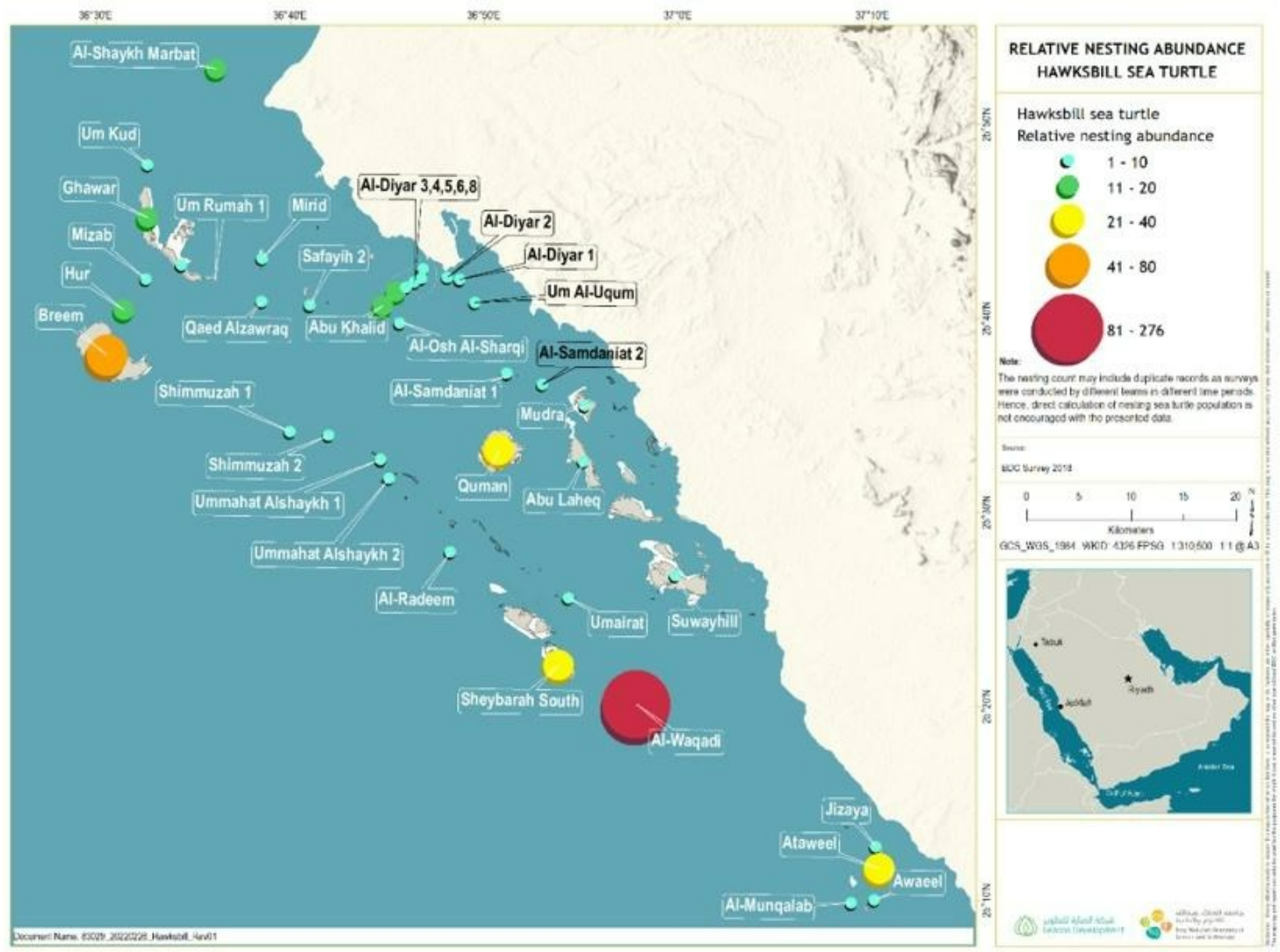


Figure 4 Main Hawksbill Nesting Sites in Red Sea



Studies Initiated by RSG

Effective management requires high-quality data. At the initiation of The Red Sea in 2017, the understanding of turtle populations was limited, with no studies having been undertaken. Between 2018 and 2020 Shimada et al (2021) undertook field studies across numerous islands and coastal areas in the northern Red Sea. RSG subsequently initiated a series of studies aimed at improving understanding of turtle populations within their areas of management to guide conservation and development planning. These studies, listed in Table 1, were undertaken by KBD on behalf of RSG, working in partnership with Five Oceans Environmental Services LLC and Pendoley Environmental.

Table 1 List of Studies Commissioned by RSG to Inform Conservation and Planning Initiatives

Study Type	Project Type	Description
Survey	Turtle Nesting Beach Surveys	Site walkover surveys on potential nesting beaches were carried out over 54 nights from 2019 to 2022. The RSG's regulatory entity, the Red Sea Zone Authority (RSZA), has also been conducting surveys of turtle nesting beaches between 2021 and 2023
	Satellite Tracking of Nesting Females	Satellite tracking of 50 Green turtles and 10 Hawksbill turtles between 2019 and 2022 using Platform Terminal Transmitter (PTT) tracking equipment. The data collected from the satellite tracking has helped reveal valuable information on distribution of key foraging and inter-nesting habitat, nesting success rates, and migration routes and behaviour during migration, both within The Red Sea project area and regionally within the wider Red Sea.
	Impact of Climate Change on Hatchling Survival	Eleven nests were assessed to estimate their hatching success values, with data loggers installed at nests to track temperature during egg incubation. Data from the studies helps inform research into the relationship between temperature and hatchling success.
	Hatchling Arena Trials (Lighting Response and Survey)	Two hatchling arena trials were undertaken to help understand the sensitivity of hatchlings to artificial light at key locations in The Red Sea area. The specific objectives were to collect hatchlings emerging from nests and subject them to *in situ* experimentation to help determine the effects of artificial lighting on orientation post-emergence.
Development of Design Guidelines	Development of Design Guidance for Mitigating Lighting Impacts on Turtle-Nesting Beaches	Design guidance aimed specifically at mitigating impacts associated with artificial lighting during masterplan design.
	Development of Design Guidance for Suitable Planting Palette on Turtle-Nesting Beaches	Guidance document aimed at providing advice on the plants that can be used to enhance turtle-nesting beaches and to shield beaches from the potential effect of artificial lighting associated with development.

Conflicts Between Coastal Development and Turtle Conservation

The Red Sea CMP established a development framework that designated development areas and established both the land use and the intensity of use within each of the areas. On this basis, the islands that are scheduled for development are largely fixed. While an environmental planning approach was applied in the development of The Red Sea CMP, turtle-nesting activity or important turtle-feeding habitat is present in the majority of development zones and conflicts between development and conservation objectives at the project level.

The risks to turtle populations associated with coastal development have been well-documented. Marine turtle-nesting beaches constitute a conservation controlling factor as they are the one habitat that cannot be replaced. Marine turtles need clear, unobstructed, and suitable beaches within which to lay their eggs. Long-term beach loss can lead to sometimes catastrophic declines in marine turtle populations as the animals are not evolutionarily adapted to settling alternate nesting sites over short-term (decadal) periods. The beach zone typically provides the central zone of conflict between the needs of breeding turtle populations and development planning. Turtles typically favour beaches that are also preferentially targeted by masterplanning teams. This may be in the form of coastal real-estate development of hotels and private residences, with associated infrastructure and hard and soft landscaping. In some instances, shoreline modifications may also be proposed to extend or realign shorelines to increase capacity or meet aesthetic objectives.

Artificial lighting on or near beaches has been shown to deter females from nesting and to disrupt nesting behaviour. On beaches exposed to light, females will nest in higher numbers in areas that are shadowed. Moving sources of artificial light may also deter nesting or cause disturbance to nesting females. Offshore lighting sources have been shown to act as an attractant to hatchlings, causing aggregation and increased risk of predation. Similarly, offshore infrastructure such as jetties act as fish aggregation devices, attracting predatory species and increasing risk of hatchling predation. Changes to local hydrodynamics can also significantly impact upon the survival rates of hatchlings.

Specific risks to turtle-nesting habitat and feeding grounds in the Red Sea that have been identified during masterplan review include proposed dredging and land reclamation, island raising to safeguard against future sea-level rise, the installation of utilities and transport infrastructure (with associated increases in maritime traffic), and construction of assets on or in close proximity to turtle-nesting beaches. Typically, the conflicts occur because the architectural firms developing the project designs are not appropriately sensitized to the ecological sensitivities of a given project site.

Design Interventions and Guidance

Capturing potential risks to turtle populations as early as possible in the design process is key as changes can be most easily effected, and negative impacts designed out, during the early pre-concept and concept design phases. To facilitate this, RSG have developed a structured approach to environmental planning that allows for robust interventions in the pre-concept design phase. The environmental design approach seeks to identify key environmental constraints and opportunities at project inception and, by working regularly with design teams to review design iterations, embed inherent protection measures into the design. The approach relies on site-

specific data and adopts the typical mitigation hierarchy, deployed from the project visioning and continued throughout the design process.

Data and guidance derived from the studies listed in Table 1 are utilized to inform and guide the masterplan design. At the pre-CMP development phase, RSG design teams and architects are informed of sensitivities associated with turtles through stage-gate workshops and iterative environmental design feedback. As the project development site is fixed, guidance aims at avoidance of impacts to the nesting beaches through modification of design, focusing on impacts associated with habitat loss and light spill.

Guidance to designers includes, but is not limited to, the following:

1. Maximise the setback distance from the back of the sandy beach, with buffers to be site-specific based on local topography and landform. A setback of minimum 50m to 100m (depending on the site requirements) for confirmed nest sites is recommended;

2. Maintain the beach and associated dunes in their natural condition such that they are not encroached upon or modified to a practicable extent. Natural vegetation to be retained;

3. Site proposed development behind topographic features that provide natural shielding so that direct visibility of lights will be obscured from view from the sea and nesting beach;

4. Install artificial shielding (such as dunes, berms, banks, vegetation, walls) or mass buildings to screen development lighting impacts at the beach; and

5. Offshore infrastructure or lighting sources (e.g. jetties, artificial islands, marinas) should not be sited on or offshore of turtle nesting beaches.

Adherence to the above covers two of the most important and effective approaches for management of light near turtle-nesting beaches:

1. To ensure there is a tall dark horizon behind the beach, and

2. To ensure there is no point sources of light visible from the beach, or on the water through which hatchlings disperse.

In addition to the above setback considerations, specific turtle-aware lighting is incorporated into design. This follows international best practice and is based on the National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia, 2020) as adopted by the Convention on the Conservation of Migratory Species of Wild Animals (CMS), of which KSA is a signatory.

Design modifications based on these guidelines have included:

- Provision of setbacks and screening to ensure protection of turtle-nesting sites;

- Designation of protection zones on development islands, where no development is permitted, specifically to ensure protection of turtle-nesting beaches;

- Implementation of protection zones restricting development offshore from turtle nesting beaches;

- Reorientation of proposed dredged channels to minimise impacts on reefs and avoid turtle-nesting habitat; and

- Elimination of design components that presented a significant risk to beach integrity and the integrity of coral reef and seagrass habitat that are located around development islands.

Recommendations for Future Management

RSG have employed a systematic planning approach that ensures key ecological data is provided to designers at the start of the project design process. This aims to ensure that inherent mitigation is embedded in the masterplan design and to avoid impacts that can most easily be accommodated through design modifications. As the design progresses, designs are updated and subject to on-going review and feedback to strengthen protections for habitat of critical importance to turtle populations.

In an area such as The Red Sea, which has until recently been data deficient, management efforts and planning guidance should employ the precautionary principle and target protection of all turtle-nesting habitat and associated feeding grounds. As has been detailed in previous sections, by engaging with designers and sensitizing them to specific risks, significant protections can be implemented on a project-by-project basis.

RSG have made efforts to enhance understanding of turtle ecology in the lagoon since project inception. For species such as turtles, where it can take many years of monitoring to understand interannual variation in population dynamics, long-term monitoring is required to build improved understanding. It is imperative that data deficiency is tackled proactively. RSG projects and any other associated developments in the area should augment turtle investigations within various project developments, collect data on key parameters (nesting ecology, immediate threats, change in territorial behaviour of turtles), and coordinate the findings of the field data with RSZA so a coherent information base/data base is established to improve the management and conservation of sea turtles.

It will be critical that RSG continue to employ a proactive approach to developing this understanding by buildin on the work already conducted and implementing sitewide monitoring and post-construction surveys at completed project sites. Maintaining the collaborative approach with open data-sharing between stakeholders will also be critical to ensure that conservation objectives can be achieved. With this in mind, a number of recommendations for future management are detailed in Table 2.

Table 2 Recommendations for Future Management

#	Description
1	Continuation of on-going monitoring of nesting beaches is critical throughout the calendar year. Nesting trends will only be determined after five to six years of continued monitoring. To improve coverage and efficiency of beach monitoring efforts across the 92 islands in the lagoon, use of unmanned aerial vehicles (UAVs) to capture data and artificial intelligence (AI) to process imagery should be trialed in monitoring activities.

#	Description
2	Ensure on-going monitoring of Phase 1 assets that are coming online through 2024. Data collected on turtle behaviour and nesting activity and success/failure should be collated and distributed to key stakeholders to inform development of later phases of the development.
3	Develop plans for the inventory and protection of nesting beaches, foraging areas, and inter-nesting/migratory habitat. The well-reasoned Australian Marine turtle Recovery Plan 2017-2027 suggests that protecting a minimum of 70% of habitat is essential for marine turtle survival - but cautions that this might not lead to population recovery. An analysis should be conducted to determine percentage loss at the end of Phase 1 and identify sites that warrant protection throughout the lagoon to meet this objective.
4	Ensure lighting design strategies are developed from the start of the project design process.
5	Where artificial beaches are created, these should be designed to mimic the physical characteristics and vegetation community structure on islands in the lagoon that support successful turtle nesting.

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