Use of MCDA to Minimize Environmental and Social Risks at Site Screening

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Introduction

The Saudi Arabian Red Sea coastline is rich in biodiversity and is home to habitats important for some of the threatened taxa in the world, including, *inter alia*, Halavi Guitarfish (*Glaucostegus halavi*), Whitespotted Whipray (*Maculabatis gerrardi*), sooty falcon (*Falco concolor*) (Sooty falcon (Vulnerable, VU)
Green Turtle (Endangered, EN)

Figure 1), Green Turtle (*Chelonia mydas*) (Sooty falcon (Vulnerable, VU) Green Turtle (Endangered, EN)

Figure 1), and *Gymnosporia parviflora,* a regionally endemic shrub.

Sooty falcon (Vulnerable, VU)

Green Turtle (Endangered, EN)

Figure 1 Critical species along the Red Sea coastline of Saudi Arabia

Red Sea Global (RSG), a subsidiary of the Public Investment Fund (PIF) of Saudi Arabia, undertook environmental screening and appraisal of multiple clusters of islands located along a 280km coastal strip in the southern Red Sea, approximately 250km south of Jeddah. (Figure 2).

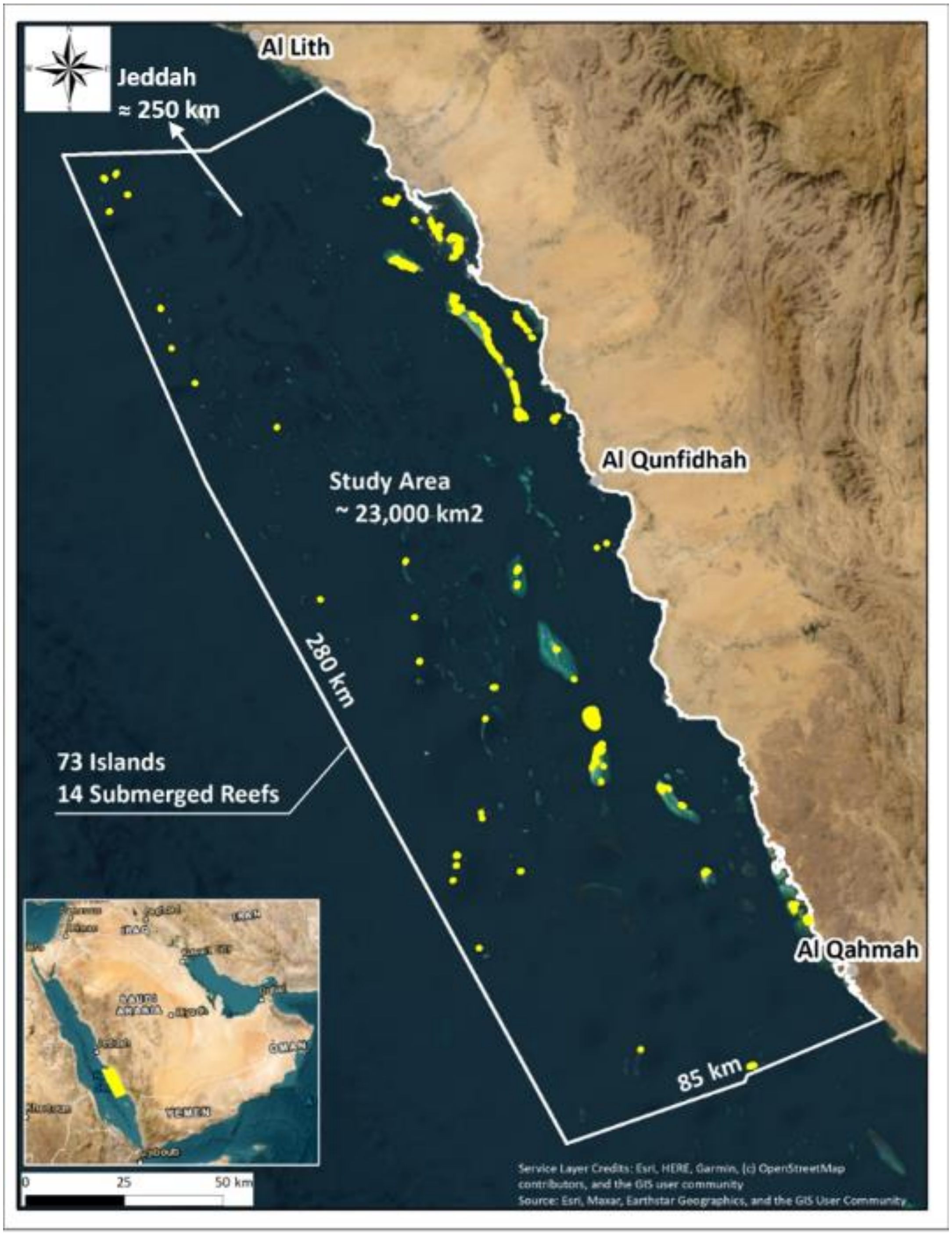

Figure 2 Project boundary

RSG embraces regenerative tourism, which is a sustainable way of traveling and discovering new places, and leaving them in better condition than how they were found. Accordingly, RSG intends to understand these habitats and their environmental, social, and ecological aspects to inform its developmental vision for these islands and the surrounding area, rooted in a regenerative concept. Hence, a screening and appraisal study was undertaken to provide a sound basis for the strategic development framework and marine spatial planning for the area. Screening and appraisal studies and their linkages with the follow-up studies are illustrated in Figure 3. This paper only covers the screening component, and Figure 3 highlights how the outcome of this component informs appraisal and other ensuing stages to mitigate environmental and social risks.

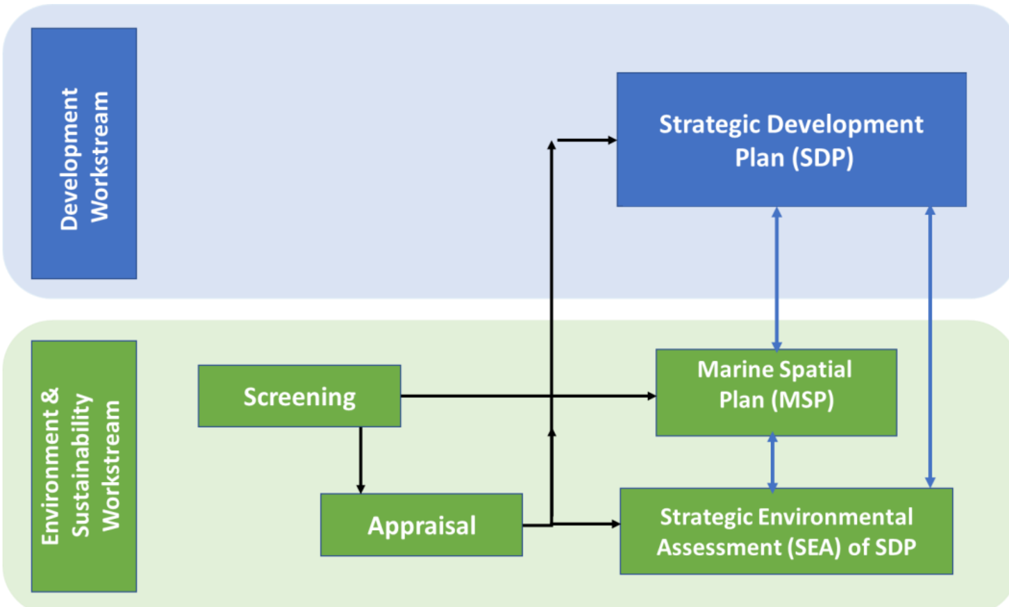

Figure 3 Process information flow

A set of screening criteria, reflecting environmental and social sensitivities were applied to characterize the Islands and their habitats to achieve comparative screening involving Multi-Criteria Decision Analysis (MCDA).

Methodology

Multi-Criteria Decision Analysis (MCDA) is an internationally accepted method that systematically supports complex decision-making scenarios involving multiple and competing objectives [1]. MCDA facilitates the process wherein stakeholders and/or decision-makers have differing priorities and perspectives on the applied screening criteria. It enables the decision-makers to rank or screen several sites/options expediently and efficiently. The greatest strength of MCDA is its ability to consider both quantitative and qualitative criteria, if the latter can be represented using a prioritized ordinal/continuous scale [2].

The MCDA undertaken by RSG involved the following four environmental and social categories for the purpose of comparative screening:

- Physical Environment
- Biological Environment
- Human Use Environment (Infrastructure/utilities used by people/society)
- Social/Socioeconomic Environment (interrelationship between society, people, and the economy)

The screening criteria layers are based on multiple rating scales. To apply MCDA, these rating scales were transformed into a comparable scale. A Pairwise Comparison Method was used for its relatively high accuracy and reliability for weighting each criterion. Standardization was performed by linear-scale transformation for comparison using a screening category scoring from 0 to 100 (Figure 4).

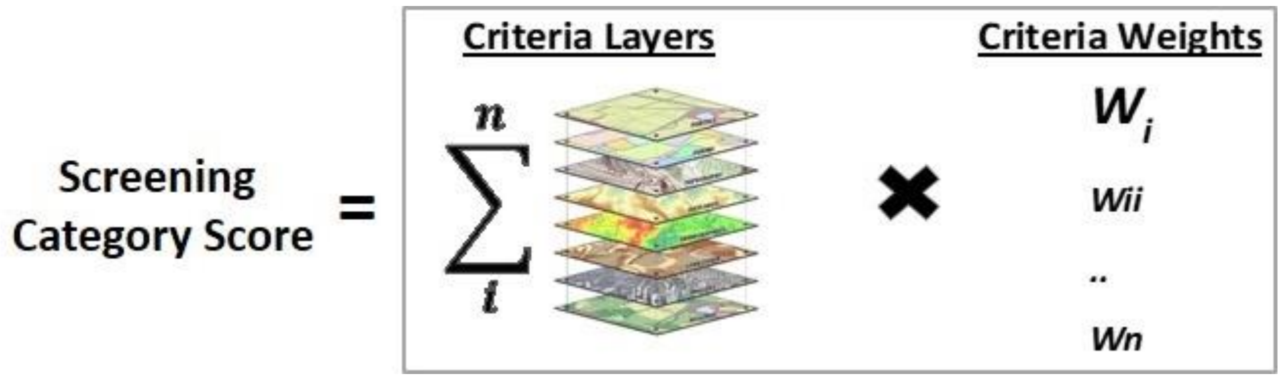

Figure 4 Screening category scoring

Screening study considered secondary data, in combination with expert judgment, for characterising and scoring of the islands using the ranking approach.

Screening Process

A set of screening criteria and their related sub-criteria were defined for the characterization of the islands/habitats under each of the four categories. The selected criteria can potentially be applied to other development projects in the Red Sea undertaken by the RSG.

Screening criteria and the sub-criteria for screening categories are presented in Figure 5.

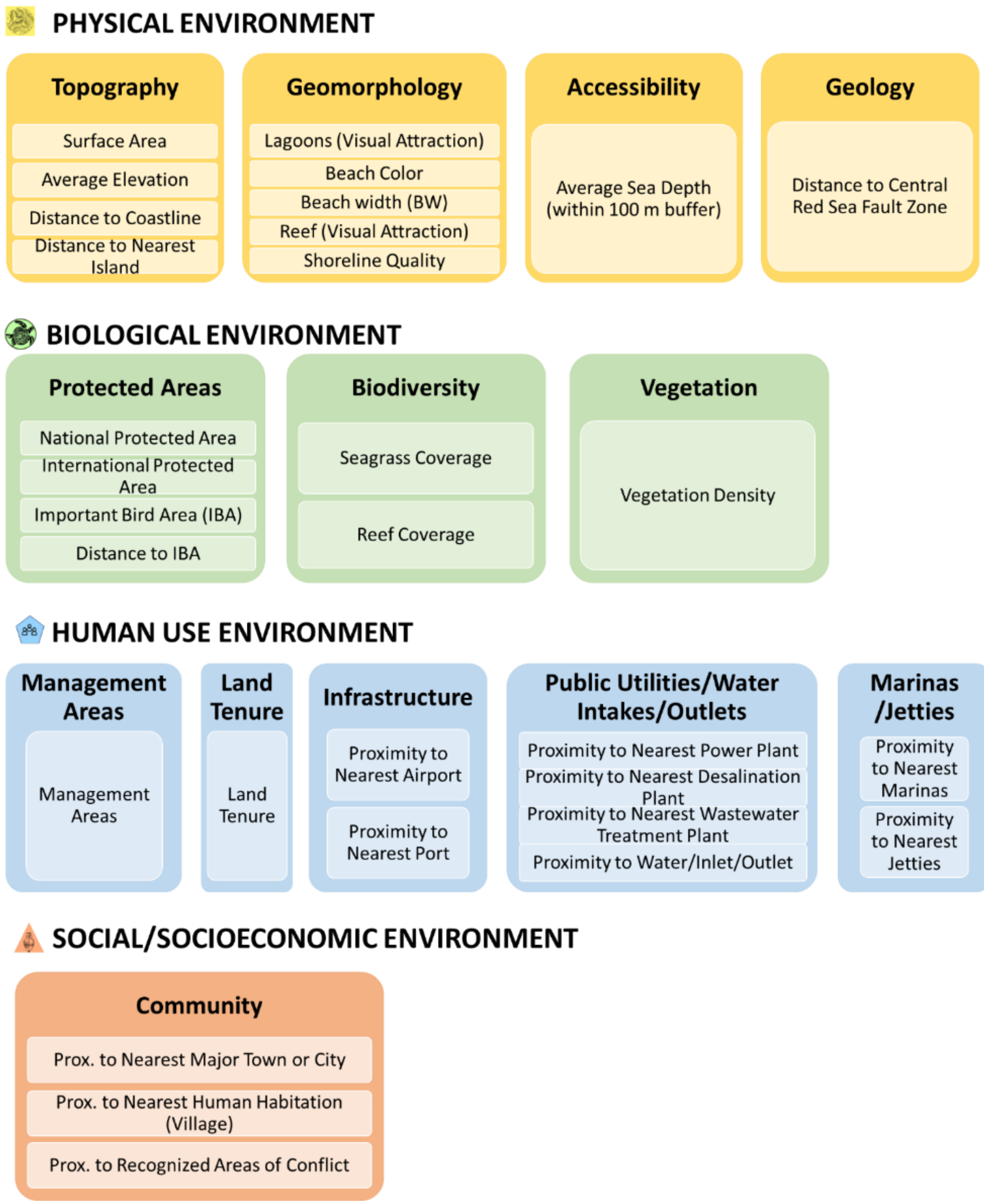

Figure 5 Screening categories with criteria and respective sub-criteria

Each sub-criteria were evaluated over five ranks, with different qualifying ranges. For instance, for 'Surface Area' (sub-criterion, scoring ranges were classified as shown in Table 1. Criteria score was the sum of all sub-criteria scores. Each sub-criteria and criteria have their weightages, and each sub-criteria have their own similar qualifying ranges.

Table 1: Example of ranked scoring for sub-criterion 'Surface Area' within Topography criterion under Physical Environment category.

CAT.	CRITERIA	SUB-CRITERIA	RANKING (R)					SUB-CRITERIA SCORE
			1	2	3	4	5	
PE	**Topography**	Surface Area (SA) [3]	1 ha<SA≤4 ha	4 ha<SA≤12 ha	12 ha<SA≤40 ha	40 ha<SA≤100 ha	SA>100 ha	

Assessing sub-criteria ranking required multidisciplinary expert judgment. For instance, the category **Physical Environment - Criteria Geomorphology**, was assessed by a geomorphologist and an ecologist. Sandy shorelines were ranked highest (5 out of 5) due to their attractiveness to visitors under sub-criterion 'Beach Color' whereas Sandy shorelines were ranked low (2 out of 5) for poor bio-richness under sub-criteria 'Shoreline Quality'. Another sub-criterion under the **Physical Environment**, **Criteria Geomorphology**, was based on the 'Beach Width' of the largest beach located on the islands. There were several lagoons in and around the islands, and lagoons were classified as: disconnected, choked, restricted, and leaky (Figure 6). Based on expert judgment, leaky lagoons scored the highest since their connection with the open sea resulted in improved water quality and high biodiversity. 'Average Elevation' was another sub-criterion within **Topography**, assessed under the physical environment category. Islands with an average elevation of 8m scored the highest whereas islands with an average elevation of less than 2m scored the lowest.

Figure 6 Different lagoon types within the project area

Seagrasses provide ecosystem services that support a wide range of fish and wildlife species, including dugong and sea turtles [4]. Hence, under the **Biological Environment** category, 'Seagrass Coverage' was ranked high by ecologists within the 'Biodiversity' sub-criteria considering the bio-richness of the islands for future ecological opportunities. Therefore, islands having seagrass coverage of more than 50% were ranked highest (5 out of 5). Designated protected areas (including potential/proposed) were considered as sub-criteria to recognize opportunities and constraints these areas present [5], [6]. 'Vegetation Density' was another sub-criterion screened under the biological environment. The dominant vegetation on the islands is halophytic species and mangroves. Halophytic vegetation plays an important role in supporting fauna species that inhabit the area, such as birds and crabs [7]. Hence, islands with vegetation coverage of more than 75% ranked the highest score whereas those with vegetation cover of less than 10% ranked the lowest score.

The **Human Use Environment** category focused on management areas (areas assigned by the state for resource use), land tenure, proximity to existing infrastructure such as airports and ports, public utilities including power plants, desalination plants, water intakes and outlets, and marinas/jetties.

The **Social/Socioeconomic Environment** category considered the interaction with the nearest town/city and recognized areas of conflict as sub-criteria within the 'Community' criterion.

Key Challenges in the Application of MCDA

Varying screening approaches

Screening of islands required diverse perspectives and use of multidisciplinary experts. At times weightages and rankings for sub-criteria/criteria varied across experts/disciplines. Hence, the selection of sub-criteria and their weightages were assigned with due considerations to balance varying screening approaches of multidisciplinary experts.

Expert Judgment

Vegetation density was calculated by digitizing the boundary of vegetation cover using 0.5m resolution satellite images. Drawing the boundaries of the sparsely distributed vegetation coverage was more subjective due to unclear vegetation boundaries.

Moreover, the shoreline habitat was categorized as rocky, sandy, sabkha, saltmarsh, and mangroves. Rankings were based on these categories in terms of biodiversity richness. Based on expert judgment (in the absence of ground verification), mangrove shorelines were considered to have high biodiversity while rocky shorelines were considered to have low biodiversity. Similarly, expert judgment helped to differentiate the mangrove vegetation and halophytic vegetation where satellite images did not provide clear differentiation when calculating mangrove density.

Climate Resilience

MCDA allowed to integrate climate resilience by ranking potential surface area that could be inundated due to sea level rise. Based on the IPCC's Sixth Assessment Report [8] and use of expert judgment, the changes in sea level according future climate change projections were analyzed and impacts due to sea level rise on each island, by the year 2100 AD, were assessed (Figure 7). Multiple global warming scenarios (based on CO_2 and related GHG projections) were considered to map surface areas at risk from sea level rise, thus informing master planners to keep the development footprint outside these areas and avoid land raising. If the potential impacts are understood, such climate-resilient designs reduce cost by not undertaking costly mitigation measures or unnecessary protection.

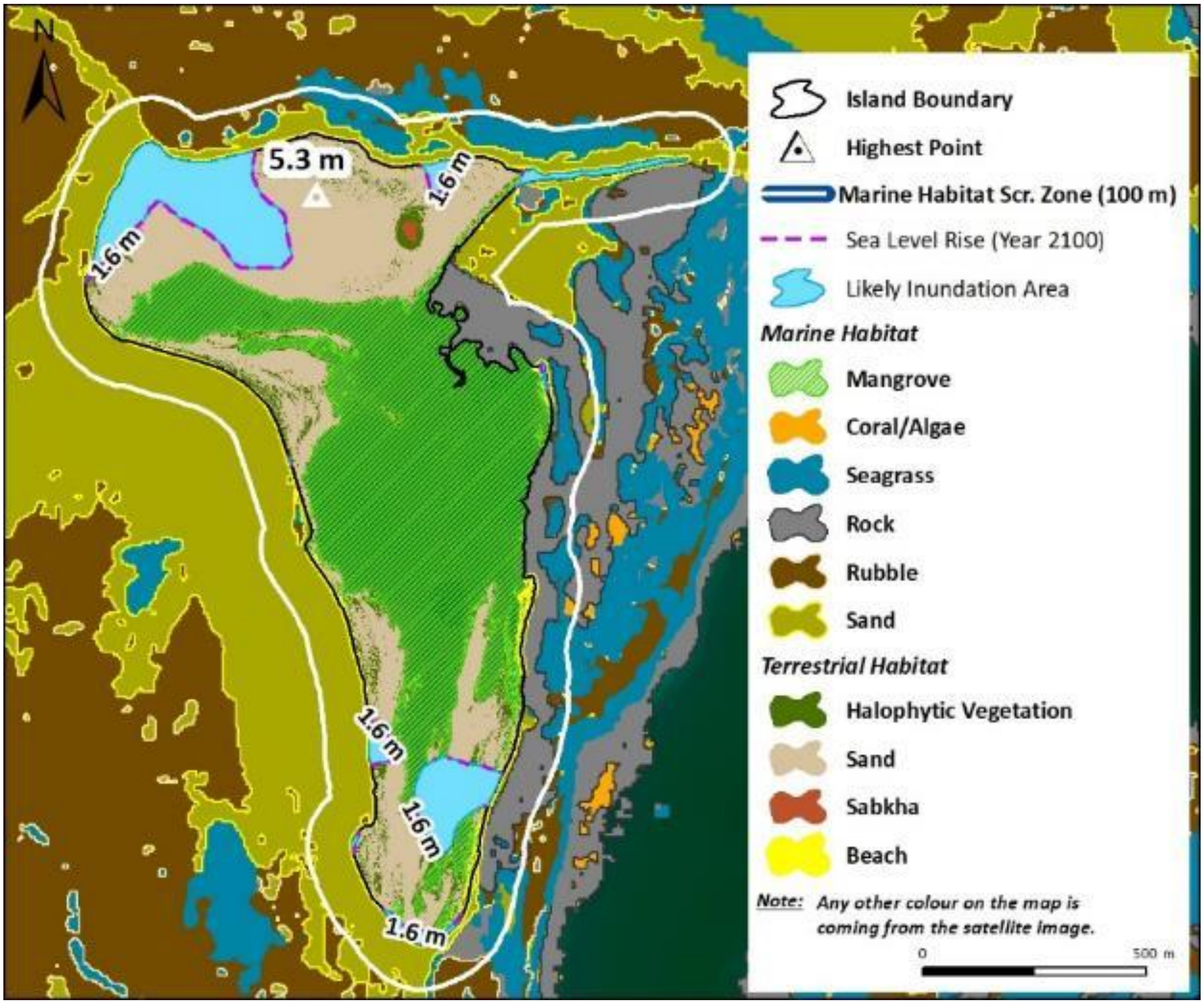

Figure 7 Likely inundation areas and habitat types (generated by using Allen Coral Atlas Data) [9]

Leveraging through drone surveys to characterize low elevated islands

Screening for average elevation was initially based on publicly available satellite images. These are of lower resolution as compared to drone-based surveys. Criteria for likely inundation areas also depended on the publicly available elevation data and it was assumed that areas lower than 1.6m will be inundated, based on the interpretation of the data provided in IPCC Sixth Assessment Report. However, it became evident that publicly available data of 1m horizontal resolution was unable to differentiate islands lower than 2m due to relatively low accuracy. To address this challenge, drone surveys were undertaken at a later stage of the project (Appraisal) to generate more accurate elevation data which could appreciate inundation areas more accurately.

Lack of Differentiation in Selected Sub-Criteria

Some of the sub-criteria selected at the screening criteria development workshop such as seismicity, relevance to protected areas, accessibility to the islands, relevance to management areas, and land tenure were expected to be effective in informing the screening. However, on application, these sub-criteria could not provide differentiation across the Islands and only resulted in a singular outcome. The main reason was relatively homogenous geographical and geological conditions across the project area, and limited management/designated areas for mining, energy, resource use, etc. in the project area. Besides, most of the land tenure in the project area is owned by the Government, which resulted in a singular outcome for this sub-criterion.

Screening criteria was applied on the Islands, including a 100m strip around each Island. Most of the surrounding marine environment around the islands was shallow with an average sea depth of less than 2m, thus not providing a very distinctive outcome for this sub-criterion. The geological formations underpinning all islands are almost similar and the distance to the existing Central Red Sea Fault Zone is almost the same, hence this sub-criterion did not provide distinctive outcome.

Conclusion

RSG applied MCDA to characterize physical, biological, human use, and social/socioeconomic aspects of 71 islands to appreciate environmental sensitivities and to inform development visioning for the area. The MCDA approach enabled RSG to assess a large number of islands over a short period providing clear and concise results. Besides the efficient review, the approach provided a quick focus on the habitat and sites of significance, saving time and effort during the ensuing appraisal stage.

The screening study and the application of the MCDA-incorporated desktop data and expert judgment to provide a quick analysis for the assessment of wide areas prior to ground-truthing studies (appraisal stage). MCDA's use during the screening study allowed for a structured, systematic, and objective approach to decision-making, reducing subjectivity and experts' preferences.

MCDA allowed for the flexibility to adjust criteria and weights based on changing circumstances or stakeholders' preferences, making it suitable for adaptive decision-making situations. Utilization of MCDA in the screening process provided a structured and transparent approach to inform decision-making that can help to identify different options while considering the multiple criteria and factors involved in the process.

The MCDA study facilitated useful discussions amongst multidisciplinary experts and decision makers. This was particularly important in situations with limited or indistinctive data on the screened islands. It also provided ground for the consideration of multi-disciplinary expert views.

Remote sensing used during the MCDA practice allowed the data to be assessed over large areas and provided a comprehensive view of the islands' physical and biological environment. The data generated by remote sensing provided input to rank terrestrial and marine habitat types of the islands, which was later verified by experts during the appraisal stage. Remote sensing data also served as a mechanism to ensure that the data used for screening was consistent.

Likely inundation areas were predicted by using different scenarios described in IPCC Sixth Assessment report to inform future master planning.

The involvement of multi-disciplinary experts provided valuable input to problem-solving and decision-making processes by drawing on diverse perspectives and expertise.

Sub-criteria – such as the seismicity, protected areas, average sea depth around the islands, management areas, and land tenure – were less useful when applying MCDA. These criteria would be more applicable with the use of further site investigations and data collection rather than at the screening stage. Hence, the selection of distinctive criteria/sub-criteria play an important to maximize MCDA utility.

This screening study can be adapted for other similar projects by changing the categories and their corresponding criteria/sub-criteria depending on the project needs.

Screening reports (a single A3 page) were prepared for each screened island covering a) key information of the island and category scores presenting the four screening categories in graphical format, b) qualitative and quantitative information on the island based on the screening categories and habitat maps, c) MCDA island category/sub-category in graphical format (Figure 8) .

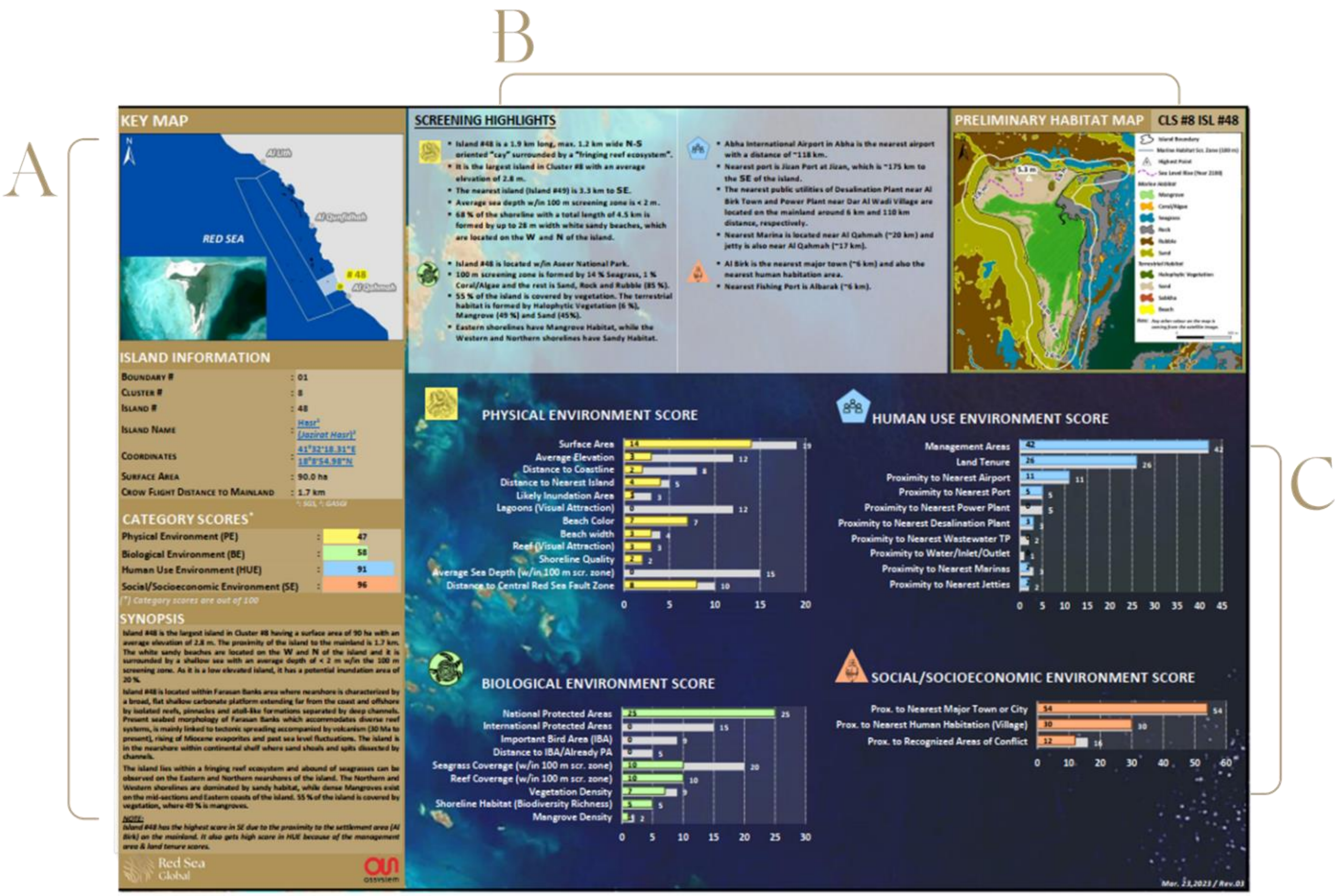

Figure 8 Sample Screening Report

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