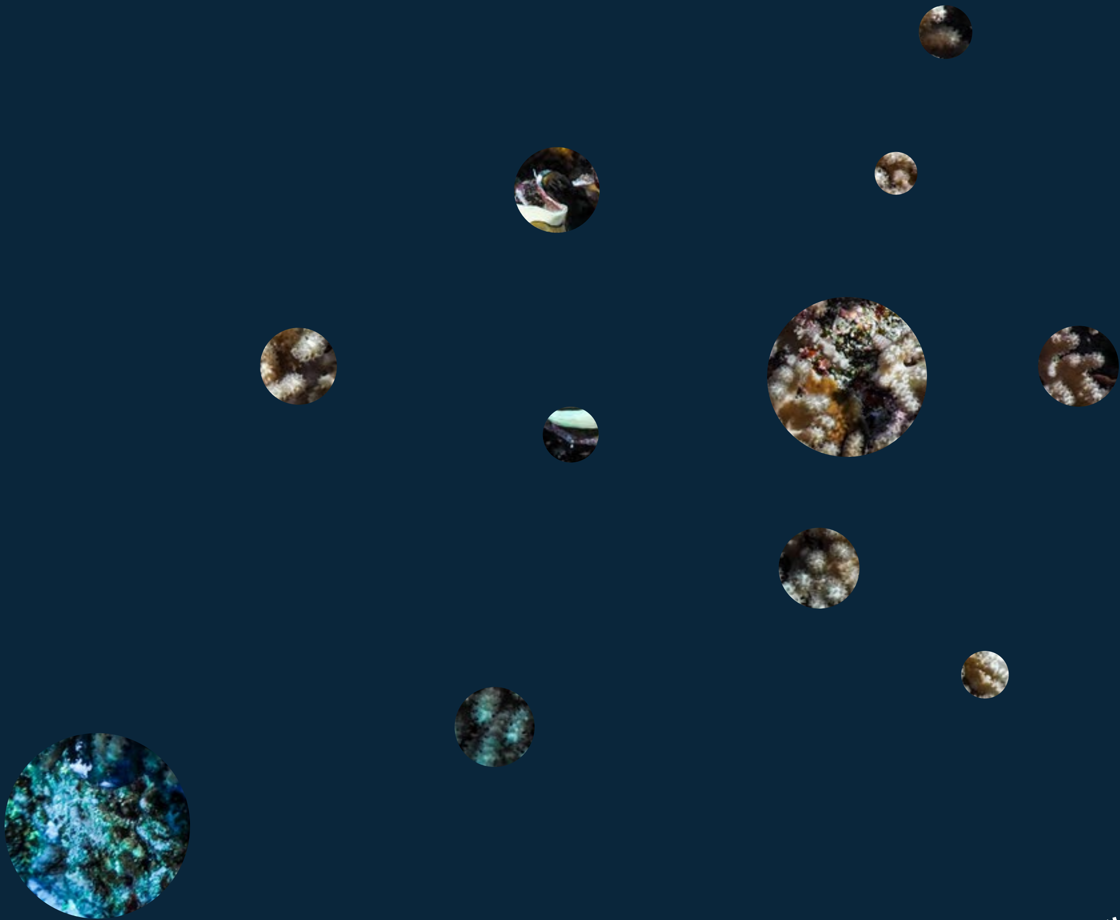
2026

SIIG MODEL

THE ROADMAP TO ACHIEVING
MEASURABLE CONSERVATION GAINS



البحر الأحمر الدولية
Red Sea Global

This report marks a significant milestone in the execution of SGI 4, titled (Achieving Net Conservation Gain of 30% by 2040).

Citation

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2026

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Red Sea Global

MESSAGE FROM JOHN PAGANO

Group Chief Executive Officer of Red Sea Global

for regenerative delivery. We ***Survey*** to document biodiversity, build scientific baselines, and establish long-term monitoring. We ***Identify*** pressures and threats facing key species and habitats. Where needed, we ***Intervene*** with targeted conservation, restoration, and regulatory actions that transform risks into opportunities for renewal. And ultimately, we measure ***Gains,*** witnessing the return of life—from nesting turtles to thriving coral communities.

The SIIG Model provides our clear roadmap to achieving the 30% NCG target. It shows how we will measure progress, restore critical habitats, strengthen ecological resilience, and protect biological communities. Most importantly, it highlights what we have already achieved—and where our regenerative journey is heading next.

I invite *you* to explore *the* SIIG Model *and* join us *in* redefining global tourism—*shaping a* future *that* is not only responsible, *but* truly regenerative.

The Red Sea has long stood as a symbol of natural beauty, biological richness, and cultural heritage. At Red Sea Global (RSG), we recognize the profound responsibility that comes with developing one of the world's most extraordinary and ecologically significant regions.

When we embarked on this journey nearly six years ago, our goal was to set a new global benchmark for sustainability. But as we envisioned the future we want to create, one truth became increasingly clear: **sustainability alone is no longer enough.** Preserving what exists is vital—but to truly safeguard this place for generations to come, we must go further. **We must regenerate.**

This conviction has shaped a more ambitious vision for RSG. Regeneration, for us, means actively restoring and enhancing the ecosystems under our stewardship—leaving the Red Sea better than we found it. This is why we have committed to one of the world's most ambitious environmental goals: achieving **30% Net Conservation Gain (NCG) by 2040** across the Red Sea Zone. Delivering on this commitment requires enhancing biodiversity—particularly within our most critical habitats—through rigorous science, innovative interventions, and nature-positive projects with measurable outcomes.

As far as Bream Island, for example—an area with no current development—we apply the full power of our ***SIIG Model,*** the RSG signature framework for regenerative delivery. We ***Survey*** to document biodiversity, build scientific baselines, and establish long-term monitoring. We ***Identify*** pressures and threats facing key species and habitats. Where needed, we ***Intervene*** with targeted conservation, restoration, and regulatory actions that transform risks into opportunities for renewal. And ultimately, we measure ***Gains,*** witnessing the return of life—from nesting turtles to thriving coral communities.

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SUMMARY

Red Sea Global has committed to one of the world's most ambitious ecological restoration targets: achieving a 30% Net Conservation Gain (NCG) by 2040.

To deliver on this commitment, we follow our science-driven SIIG Model, through which we continuously ***Survey*** ecosystems, ***Identify*** threats, ***Intervene*** through targeted conservation and restoration, and forecast the ***Gains*** we can achieve.

Using this model, we have identified **eight priority marine habitats and species groups** that are essential to maintaining the ecological integrity of the Red Sea. For each, we provide an assessment of current condition, key pressures, and the highest-impact conservation and enhancement actions needed to restore ecosystem health, build resilience, and achieve measurable biodiversity gains across the destination.

To track progress and quantify outcomes, we outline a **biodiversity scoring framework** that evaluates ecological status and long-term trends for each habitat and species group. This framework informs the monitoring programs required to measure advancement toward our biodiversity targets. Using this scoring system, we also present **predicted conservation gains achievable by 2040,** based on current and planned conservation actions. Where possible, these predictions draw on evidence from comparable global interventions; where data are limited, we provide clear justifications for gain estimates.

Across habitats, **the largest gains** are expected from removing or reducing pressures, particularly fishing and human disturbance—allowing species and ecosystems to recover naturally and re-establish ecological processes that support long-term resilience. **Active enhancement approaches** such as nurseries and out-planting, artificial reefs, nest boxes, or invasive species control, also contribute measurable gains. For example, rodent eradication on islands has repeatedly resulted in dramatic rebounds of seabird breeding populations. However, active habitat enhancement is often resource-intensive and challenging to scale. While future innovations may greatly improve cost-efficiency, the gains presented here reflect only projects currently underway or in active planning, making our estimates conservative for some habitats.

Overall, applying the SIIG Model makes achieving a **30% NCG by 2040 both realistic and attainable,** although expected gains vary among habitats and species. Because the most significant gains depend on reducing fishery impacts, success will require establishing and maintaining extensive zones with strict limits on extractive fishing. Full ecosystem recovery and the largest measurable gains will take time, reinforcing the need for sustained long-term management and **high-quality monitoring programs** capable of supporting credible reporting and effective adaptive decision-making.

Conservation Priority Habitats & Species Groups

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

INTRODUCTION:

No Net Loss and Beyond

01.

Globally, many countries hosting unique natural features have placed biodiversity conservation and restoration at the heart of their environmental agendas[1,2]. Through diverse strategies and initiatives, they have pursued both national and international conservation targets, with approaches shaped by national priorities, ecological contexts, and socio-economic realities.

To balance environmental protection with economic growth and development, the Sustainable Development Goals (SDGs) provide a guiding framework. Notably:

SDG 9 encourages building resilient infrastructure to support sustainable development.

SDG 14 calls for the conservation and sustainable use of oceans, seas, and marine resources.

SDG 15 emphasizes the protection, restoration, and sustainable use of terrestrial ecosystems, including forests, land, and biodiversity.

To implement these biodiversity-related goals, governments increasingly integrate them into Environmental and Social Impact Assessments (ESIAs) and National Biodiversity Action Plans (NBAPs). Furthermore, policies such as "No Net Loss" (NNL) are gaining traction globally, particularly among international funding agencies like the International Finance Corporation (IFC), ensuring that development projects contribute to biodiversity conservation rather than erode it[3–5].

NET CONSERVATION GAIN FROM "NO NET LOSS" TO REGENERATION

The United Kingdom has pioneered a regenerative approach to development, which has raised the global bar by moving beyond the principle of "No Net Loss" toward measurable net-positive biodiversity outcomes.

As of February 2024, all new developments in England are legally required to deliver a minimum of 10% Biodiversity Net Gain (BNG) by a well-defined timeframe[6]. In essence, BNG ensures that any development activity leaves the natural environment in a measurably better state than it was before. This approach—sometimes also referred to as Biodiversity Net Positive Conservation Benefit or Value—places biodiversity improvement at the heart of development.

To comply, developers must prepare detailed BNG action plans, which include at minimum:

BIODIVERSITY GAIN IMPLEMENTATION PLAN: Outlining strategies to achieve required biodiversity improvements through long-term restoration, conservation, and enhancement programs, subject to approval by local planning authorities.

BASELINE ASSESSMENTS: Conducting standardized biodiversity studies that measure habitat size, quality, type, and location to establish the starting point in biodiversity units.

BNG METRIC: Applying a standardized calculation tool to quantify biodiversity units and determine the required gains.

LONG-TERM MONITORING: Ensuring created or enhanced habitats are maintained and monitored over time to validate biodiversity improvements.

The UK's mandatory BNG framework provides a powerful model for regenerative development, ensuring that growth and conservation work hand in hand to leave lasting positive impacts on ecosystems and communities[6,7]. Nearly six years ago, RSG embraced this very philosophy—but on a far more ambitious scale. While the UK mandates a 10% BNG, RSG has voluntarily set its sights on achieving a 30% conservation gain across our entire Red Sea Zone (RSZ) by 2040. This commitment not only builds on the principles of BNG but goes further: moving from conservation to active regeneration, ensuring the RSZ is left in a significantly richer and more resilient ecological state for generations to come.

RED SEA ZONE BIODIVERSITY FEATURES, CHALLENGES AND OPPORTUNITIES

The RSZ, which comprises both the Red Sea and AMAALA destinations in the Northern Red Sea (Figure 1), is an area with enormous conservation significance. It contains vibrant coral reefs, extensive seagrass meadows, widespread soft-bottom habitats. Its 90 islands host 30,000 seabird breeding pairs every year, and more than 450 female sea-turtles nest on its beaches. We have recorded 40 globally or regionally threatened marine species within the area, including 6 that are critically endangered and 17 endangered. These include priority species such as Humpback dolphin, Halavi guitarfish, Dugong and Sooty falcon.

A key geographic feature is the Al Wajh Lagoon, by far the largest lagoon in the Red Sea at nearly 2,000 km^2 and with enormous variety of habitats and environmental conditions that sustains a diversity of rare and threatened marine wildlife that is probably unique in the region[8]. The lagoon has been recognized as both an 'Important Shark and Ray Area' by IUCN[9], and an 'Important Bird Area' by Bird Life International[10].

ACHIEVING SUBSTANTIAL AND MEASURABLE MARINE CONSERVATION GAINS

As part of its regenerative approach, RSG has committed to ambitious biodiversity conservation goals including achieving a NCG of 30% by 2040. Achieving that goal will require sustained and focused commitment.

Appling the SIIG Model provides a roadmap to achieving that goal for our marine ecosystems, which involves

- Selecting focal habitats and species groups – those with high biodiversity and ecological significance.
- Developing a conservation scoring approach to quantify status and progress towards our target.
- Identifying the key conservation actions necessary to achieve major gains for each group.
- Predicting realistic gains from those interventions by 2040, based on evidence from similar actions elsewhere or, when that's not possible, other explicit justification.

CONTRIBUTING TO NATIONAL AND REGIONAL CONSERVATION GOALS

In addition to the many other desirable outcomes, effective conservation of this special place will also contribute to national goals including:

- The larger Saudi Green Initiative target to have 30% of the Kingdom's land and sea effectively protected by 2030 (https://www.greeninitiatives.gov.sa/about-sgi/sgi-targets/protecting-land-and-sea/).
- Kunming-Montreal Global Biodiversity Framework (https://www.cbd.int/gbf), which has 23 targets for 2030, including the target to 'conserve 30% of Land, Waters, and Sea', as well as other targets for biodiversity restoration and enhancement.

Figure 1 | The map shows the boundaries of the Red Sea Zone which includes The Red Sea and AMAALA both equals to a total area (marine and terrestrial) 20,530.19 km^2

PRIORITY

Habitats & Species

02.

The robust baseline data we have accumulated over the past few years enabled us to identify priority marine habitats and species groups. This is based on their spatial extent or abundance, the biodiversity they contain or sustain, their conservation status, and whether RSZ is or might become a regionally or globally significant area for them (Table 1). Based on our SIIG Model, we identified the groups our enhancement efforts are focused on. For each of these we – below – describe status, identify threats and conservation opportunities, and highlight specific interventions that will meaningfully improve their population size or condition.

Table 01 | Conservation Priority Habitats & Species Groups

Habitat or Species Group	Justification
Coral reefs	Widespread (~80 km^2 in RSZ) and hyper-diverse habitats that support abundant marine life. Globally imperiled by climate change, but with potential for RSZ to be a significant conservation area due to high natural resilience of northern Red Sea reefs. High variability in environmental conditions and habitats within the Al Wajh lagoon has created micro-environments which may harbor especially climate-resilient genotypes.
Seagrass	Widespread in RSZ (~97 km^2 with seagrass present). Important for carbon sequestration, as nursery habitat for many species, and as feeding areas for species including Green turtles, Dugong, and several rays. Declining globally due to coastal development, climate change and water quality degradation.
Red mangroves	There are two local species of mangroves: Red and Grey mangrove. Enhancement of the most widespread species, grey mangrove, is part of the NNL mitigation program. We focus on Red mangroves, which are more spatially limited (~0.4 km^2). Al Wajh lagoon is regionally important for this species, which plays a role in erosion protection, water quality regulation, nutrient recycling, mitigation of sea level rise by sediment trapping, carbon sequestration, provides nursery habitat for marine species, and is habitat used by birds and other animals.
Reef fishes	Highly diverse group with around 1,000 species found in the Red Sea and, already, more than 400 recorded during our coral reef surveys. Reef fishes constitute the major portion of marine biomass, and are the food base for species including dolphins, sharks and seabirds. There are several high priority species including the endangered Humphead wrasse and Sky emperor, and many threatened species, including the majority of large-bodied groupers.
Sharks & rays	Sharks and rays are among the most threatened group of animals in the world. The diversity of habitats within the area provides habitats for many of these species. Already, 26 threatened shark and ray species have been observed within RSZ waters, including the critically endangered Halavi guitarfish, White-spotted wedgefish, and Hammerhead shark. In 2023, the Al Wajh lagoon was declared an Important Shark and Ray Area by IUCN. Ongoing surveys of lagoon habitats are reinforcing the importance of the lagoon for several highly threatened species.
Sea turtles	The RSZ has some of the most important nesting beaches in the entire Red Sea Region for both the critically endangered Hawksbill turtle and the Green turtle (Waqadi Island for Hawksbill, and Breem for Green turtles). Estimated populations of nesting females are ~234 Hawksbills and 231 Greens, with about one third of those nesting in any particular year.
Seabirds & island birds	At least 14 species of island birds breed within the RSZ, with around 25,000 breeding pairs every year. The Al Wajh Bank has been declared as an Important Bird Area (IBA) by BirdLife international due to its importance for Sooty falcon (regionally endangered), Sooty gull, White-eyed gull and Crab plover (regionally vulnerable). RSZ habitats are a regional and global hotspot for those and other species, hosting significant percentages of global breeding populations of: Sooty falcon (2-3 %), Crab plover (5%), Sooty gull (17%–35%), White-eyed gull (15%), Bridled tern (1%), White-cheeked tern (4%), and Lesser crested tern (2%).
Marine mammals	9 species of marine mammal have been recorded in RSZ waters. Highest conservation priority species are the endangered Indian Ocean Humpback dolphin and the vulnerable and highly ecologically distinctive Dugong. Spinner and Bottlenose dolphins are the most encountered species and both likely have important breeding areas within and around the Al Wajh lagoon.

MEASURING CONSERVATION

Status & Progress

03.

Without good information it is difficult to develop effective conservation programs, and it is impossible to assess the effectiveness of interventions. Therefore, we identify both suitable indicators and associated data needs necessary to assess the status and trends of each priority habitat and species.

DATA AND INDICATOR REQUIREMENTS

For each target group we identify 1 to 3 suitable indicators of conservation status. Selected indicators are already widely used in conservation and management and have natural meaning. They measure key features of populations, representing biodiversity values such as abundance, spatial extent, condition, and/or reproductive success.

As our goal is to achieve net population-scale conservation gains, it is essential that baseline and long-term monitoring data truly represent our habitats and species at all-RSZ scale. Most of the identified data needs are covered by established monitoring programs and already have robust baseline data, but where those are not yet implemented, we also outline requirements for suitable programs.

To combine scores from component indicators into overall scores for habitats or species groups, it is necessary to weight each indicator, with highest weights given to indicators that are the most important measures of population size or condition. Details of selected indicators, weighting, and survey programs for each habitat and species group are given in their respective sections below.

QUANTIFYING CONSERVATION PROGRESS AND BIODIVERSITY GAINS

To estimate overall RSZ conservation status and gain, we must weight habitats and species groups so component indicator scores can be pooled to higher levels. In Table 2 we weight these based on best judgment of importance to biodiversity. Weighting has some inherent subjectivity but is intended to account for spatial extent, population size, diversity, vulnerability, and ecological function.

Half (50%) of the overall weight was allocated to coral reef habitats and associated species (reef fishes and reef-associated sharks and rays) and the remaining 50% was allocated to the other habitats and species. The high weighting of coral reefs reflects their exceptional biodiversity, their wide extent (nearly 100 km² of complex shallow reefs, several hundred km² more of sparse and deeper coral habitats), their imperiled status due to climate change, and the likely regional and potentially global importance of RSZ reefs. High weights are given to habitats and species groups that are abundant, widespread and diverse, those that contain large numbers of high priority species, and those that provide significant ecosystem services (e.g. sustain other species or contribute to other conservation goals such as through carbon sequestration) as shown in Table 2.

Table 02 | Habitat and Species Group Weighting

Habitat or Species Group	Weight	Explanation
Coral Reef Habitats & Species	**50%**	Widespread in RSZ, they harbor exceptional and highly threatened biodiversity. The variety of habitats and environments within the RSZ, particularly Al Wajh lagoon, makes the RSZ a coral biodiversity hotspot.
Corals	25%	Foundational species. RSZ corals have high global significance due to the relative resilience of northern Red Sea corals to global warming.
Coral Associated Species (reef fishes, sharks & rays)	25%	Reef fish (20%) are exceptionally diverse and comprise by far the largest component of marine biomass. They are prey for sharks and seabirds. Recovery of reef fishes enhances coral resilience through restoration of processes such as herbivory that favor corals. Reef-associated sharks (5%) are regionally depleted and include several threatened species with high potential for recovery.
Other Habitats and Species	**50%**	
Seagrass Habitat	10%	Seagrass is extensive (~97 km²) but largely composed of sparse meadows (<20% coverage) which generally support low levels of biodiversity. Seagrass species are not by themselves priority species, but, collectively, seagrass meadows are important foraging areas for Dugong, Green turtles and rays, and play a role in carbon sequestration.
Red Mangrove Habitat	5%	Relatively limited extent (~0.4 km²) but RSZ is ecologically important for this species, which supports biodiversity by providing habitat, shelter, and feeding areas, and other ecosystem services such as coastal protection and carbon sequestration.
Sea Turtles	10%	Green turtles although not threatened are considered important species. Hawksbill turtles are critically endangered. RSZ contains regionally significant populations, and highly important nesting beaches for both species (Breem and Waqadi islands).
Marine Mammals	10%	Includes Dugong and 8 species of dolphin. Highest priority species are Humpback dolphin and Dugong, both highly vulnerable, ecologically distinctive, and with potential for RSZ to become a regionally significant conservation area.
Other Sharks & Rays	5%	Sharks and rays are among the most threatened groups of animals in the world. RSZ non reef habitats are important for several priority species including the critically endangered Halavi guitarfish, and other rays.
Island Birds	10%	Al Wajh lagoon recognized as an Important Bird Area by Bird Life International. Around 30,000 breeding pairs in RSZ per year, including the regionally endangered Sooty Falcon and the regionally vulnerable and globally declining Crab plover.

As detailed in sections below, there are 1 to 3 weighted component indicators within each habitat or species group. The overall conservation status scoring system is therefore hierarchical, and conservation scores and progress can be calculated at multiple levels – for individual indicators, pooled up to habitat or species groups, or at the scale of all RSZ marine (Figure 2).

Scores for each indicator at any time represent their status relative to baseline, and the overall score for a group is the weighted average of its component indicators.

For example, seagrass, coverage in high quality habitats is weighted at 7/10 and coverage in other habitats is weighted 3/10. If total cover of seagrass in high quality habitat increases by 10% and cover in other habitats by 20%, overall seagrass gain would be 0.7 x 10% + 0.3 x 20% = 13%. Scores for habitat and species groups can be similarly pooled up to an overall marine conservation progress score.

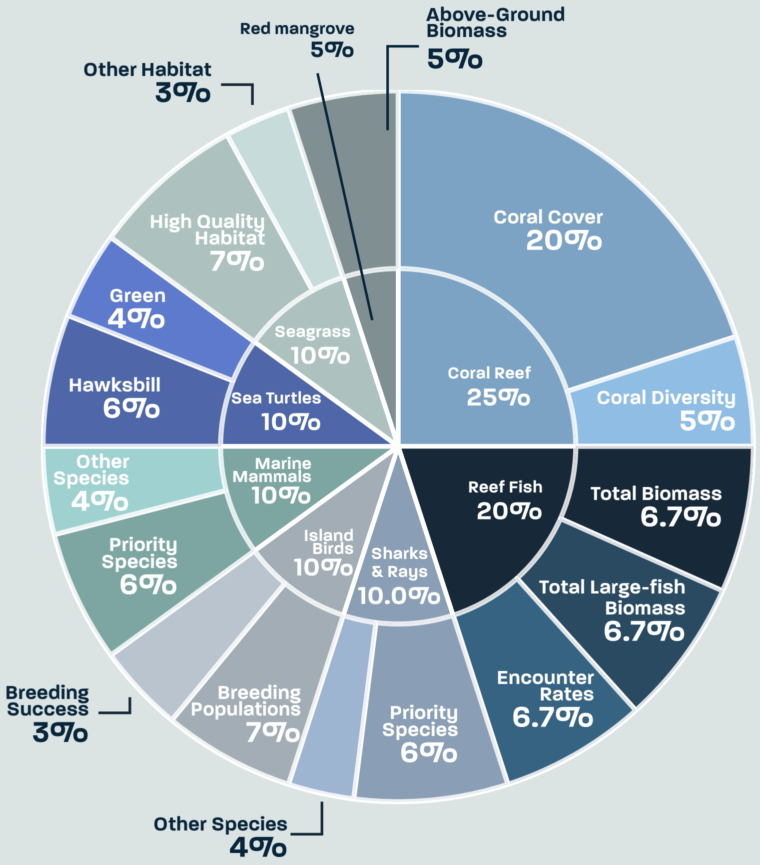

Figure 2 | Inner circle represents priority habitat and species groups and their weighting, and outer circle represents the indicators for each group.

PREDICTING CONSERVATION IMPACTS

In sections below, we report status and main threats for each habitat and species group, outline the most important conservation and enhancement interventions underway or planned, and predict realistic gains from those interventions by 2040.

Predictions of conservation impact reflect outcomes from the proposed conservation actions compared to no-action, i.e. predicted future status without those interventions. In most cases, predictions and conservation gain scoring are made relative to an existing baseline. These estimates do not account for potential impacts from development of the area – as it is a requirement that any such impacts are managed under the developer's mitigation hierarchy to ensure no net loss of biodiversity values. The NNL mitigation hierarchy sequentially aims to avoid, minimize, restore, and offset any development related impacts.

In tracking progress, it is essential to account for larger-scale factors affecting our ecosystems. Climate change is a major risk for nearly all marine ecosystems, but particularly for coral reefs [11–13]. We do not attempt to calculate expected impacts of climate change on marine habitats and species, in part because of the inherent complexity of that, but, more fundamentally, because, as described above, our goal is to predict conservation benefits from our interventions relative to no action.

However, to the extent possible, our conservation management and interventions are designed to increase climate resilience and recovery potential. For corals, this includes selective breeding of resilient corals as well as targeted coral outplanting to accelerate recovery at sites impacted by bleaching. Central to our conservation approach is protection and recovery of fish populations to restore the natural ecological balance that favors corals over their competitors.

More generally, our conservation approach is based on these principles:

· Conservation and enhancement interventions must be appropriate for expected conditions through 2040 and beyond and must be adaptive - i.e., responsive to changing conditions.
· Where feasible, interventions that promote climate resilience should be favored.
· Scoring of conservation progress must account for background trends in habitat or species status, so that we can properly measure the net benefits arising from our actions.

PREDICTING

Conservation Impacts

04.

SIIG: CORAL REEFS

KEY ACTIVITIES

- Restoration of fish stocks to restore natural ecological processes
- Accelerating reef recovery through propagation and out-planting
- High-value artificial reefs
- Mooring buoys and anchoring restrictions

INDICATORS

- Coral cover
- Coral generic diversity

POTENTIAL NCG BY 2040

5%

Status & Threats

RSZ coral communities are extremely diverse, with 72 genera and around 300 species of reef-building corals present in the Northern Red Sea region[14]. Coral cover varies from a few percent to 50-60% among surveyed reefs, depending on depth, exposure, distance from shore, ambient turbidity and seawater chemistry. Generally, highest coral cover occurs on outer reefs and reef crests.

Ongoing ocean warming is an existential threat for coral reefs globally. There is good evidence that northern Red Sea reefs, including those in RSZ, are much more resilient to elevated temperatures than reefs in most of the world[15]. Despite this relative resilience, national and regional authorities have observed bleaching events across the entire Red Sea in 2020, 2023, and 2024, with 2024 being the most severe event yet recorded in this region. Consequences of such bleaching events can include direct coral mortality, increased vulnerability to other stressors, and reduced reproductive output of surviving corals for a year or more. It is therefore essential to minimize manageable stressors during and after bleaching events, to give our corals the greatest ability to recover and persist. Likely, the most important manageable stressor is fishing, which impacts coral reefs in two main ways: cumulative damage from the thousands of times each year that fishing boat anchors break, abrade, or dislodge corals[16,17]; and from the loss of ecological balance caused by overharvesting of herbivorous fishes and invertivores. Reefs with intact fish populations tend to be better environments for corals, because abundant feeding fishes control the algae that compete with corals as well as reducing populations of coral-predators such as the crown-of-thorns sea star[18].

Corals are also susceptible to excessive sedimentation and poor water quality, but the capacity to tolerate such conditions is highly variable among taxa and individual colonies, and rich coral communities can develop in seemingly poor environments. However, most coral communities are vulnerable to rapid change in these conditions.

Enhancement Efforts

Larval propagation and micro-fragging for reef-scale restoration. Larval propagation involves capturing gametes from spawning corals and using those to produce juveniles. Micro-fragging involves cutting colonies into small pieces that are capable of rapid regeneration into new colonies[19,20]. Both these approaches create large numbers of corals that can be outplanted onto reefs. The coral breeding laboratory established in 2024 (Figure 3) enables us to selectively breed from colonies that have desirable qualities, such as higher resilience to heat stress[21], and to control the timing of production of larvae so that outplant material is available throughout the year. It also provides a controlled environment to rear highly sensitive early-juvenile phase corals until they reach a sufficient size to have high survivorship in the wild. Large-scale out-planting of corals along these lines has been shown to kickstart recovery of reefs impacted by disturbances such as mass bleaching events[22].

LARVAL PROPAGATION AND MICRO-FRAGGING FOR REEF-SCALE RESTORATION

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CORAL GARDENING AND REEF BUILDING

Create new reefs or enhance existing ones by transferring corals onto reefs or artificial structures. Our source corals are ones previously relocated out of the footprint of planned marine works. Mariculture of these corals in nurseries provides a steady supply of corals and coral fragments. We are testing artificial reef substrates to create environments that not only have good outcomes for corals, but also can become self-sustaining, productive systems that support other marine life.

Figure 3 | Modular artificial reef, Coral breeding facility, and coral outplants ready for transfer to reef.

RESTORATION OF NATURAL PROCESS OF HERBIVORY

Probably the most important enhancement approach for corals is to restore coral reefs to natural systems with abundant and diverse fish communities that provide optimal conditions for coral growth, reproduction, and resilience. Impacts of this on corals can be highly significant[18]. A study of 30 global Marine Protected Areas (MPAs) found that large, well-enforced, no-take MPAs had on average 8-19% more coral cover than nearby unprotected reefs[23]. Other large-scale studies have also shown better outcomes for corals inside MPAs than outside[24,25], including improved recovery following bleaching events[26].

ANCHORING REGULATION AND ESTABLISHMENT OF MOORING BUOY NETWORK

Recent establishment of a mooring network will reduce anchoring impact, especially if allied with enforcement of existing regulations that prohibit anchoring on coral reefs, and additional regulation to prohibit the most destructive anchor types.

Data Sources & Indicators

RSZ corals and coral reefs are surveyed using two approaches: photo-quadrats taken during fish and habitat surveys, and structure from motion survey (SfM). A total of 360 fish and habitat sites and 170 SfM sites were surveyed for the 2021-2022 baseline, and around one third of those are resurveyed every year. Data are extracted from survey imagery using a machine learning tool - CoralNet[27]. Indicators are coral cover (80% of score), the most widely used measure of coral reef condition and best feasible measure of total coral population size, and coral generic diversity (20%), a proxy for the functional diversity that sustains the full suite of services and habitat values provided by coral reefs.

SIIG: RED MANGROVES

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Nurseries & afforestation · Pollination enhancement · Grazer management (fencing)	Above Ground Biomass	8%

Status & Threats

The RSZ is inhabited by two species of mangroves, *Avicennia marina* (grey mangrove) and *Rhizophora mucronata* (red mangrove). These are the only mangrove species salt-tolerant enough to thrive in the Red Sea, a hyper-saline basin. However, red mangroves are relatively sensitive to strong currents and, hence, their distribution is limited to sheltered sites. Consequently, of the more than 26 km^2 of mangrove habitat in the RSZ, only ~ 0.4 km^2 are red mangrove forest. The Al Wajh lagoon is particularly important for red mangrove, due to the presence of protected low-current sites. Indeed, it is the only Northern Red Sea site with red mangrove, which are otherwise in Saudi Arabia found only in the Farasan banks and islands[28].

Red mangrove is not considered as threatened by IUCN. However, globally, the species is declining, as are mangroves more generally. It is estimated that around one third of global mangrove forests have been lost since 1980, with annual decline between 0.04 and 1%[29,30]. Climate change and sea level rise also threaten the long-term persistence of mangroves in the region. In fact, under a high-sea level rise scenario, most mangroves of the Red Sea and Gulf of Aden will be submerged in 40 years, as their ability to accumulate sediment likely wouldn't keep pace with sea level rises. Because of the above, the IUCN list of ecosystem assessments categories mangroves of the Red Sea and Gulf of Aden as endangered[31]. The main threat for coastal mangroves is from camel grazing, which affects recruitment too, as camels also graze upon propagules and seedlings. We also have developing understanding that harsh conditions in our area, including very high summer temperatures, may limit populations of insect pollinators. As a result, most pollination is from wind or self-pollination (i.e. plants pollinating themselves), with negative consequences for pollination rates and for forests' genetic diversity.

Enhancement Efforts

Much of the suitable area for mangrove enhancement in RSZ has been committed to other purposes, including mangrove replanting for the NNL mitigation program. This constrains potential for enhancement and is why we focus our efforts on red mangroves, the more threatened and rarer species.

NURSERIES & AFFORESTATION

Some areas with conditions suitable for mangrove growth, are unvegetated or under-vegetated due to propagule limitation. For red mangroves, the extent of such suitable and available areas is estimated to be ~24,000 m^2. Planting seedlings in these areas would allow for mangrove enrichment and afforestation. Nurseries play a key role in increasing availability of suitable seedlings through two main factors. First, propagules in managed nurseries have significantly higher germination rates, and secondly, because moving propagules to nurseries reduces the loss of otherwise viable propagules that, in nature, fail to find suitable substrate to root.

GRAZER MANAGEMENT through fencing or otherwise is essential for enhancement efforts in coastal or nearshore island habitats. Without it, there is high risk of major loss of natural recruits and out-planted seedlings, along with continued impacts to mature plants.

POLLINATION ENHANCEMENT from introduction of pollinators such as honeybees can enhance fruit and propagule production, as well as decreasing rates of self-pollination. Results from a 2024 pilot study are extremely promising, as the introduction of honeybees to a red mangrove area enhanced pollination rates 3-fold and fruit set 20-fold. Assuming this corresponds to comparably higher levels of propagule production, there is enormous potential for this approach to increase the quantity of propagules and seedlings available for enhancement.

Figure 4 | Mangrove fencing, nursery, and introduction of honeybees

GEOENGINEERING involves restructuring landscapes to change hydrodynamics and therefore extent to which areas are tidally flooded or not. This has potential to significantly increase the extent of habitat suitable for mangrove afforestation, but at high cost per area modified. Although not part of our current enhancement strategy, it could be suitable for particularly very high value areas.

Data Sources & Indicators

Mangrove aerial extent is estimated from drone surveys. Surveys in 2023 gathered high resolution RGB and multi-spectral imagery for all RSZ mangrove areas. Baseline estimated red mangrove areal coverage was derived from manual digitization of polygons in RGB images. Improved estimates of mangrove coverage and density can be obtained from semi-automatic classification of imagery. Representative sampling of tree attributes (height, diameter, crown area) provides a means to estimate above ground biomass (AGB), our red mangrove conservation status indicator.

SIIG: SEA GRASS

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Transplanting · (possible) Nurseries for suitable species	· Total seagrass within high-quality habitat · Total seagrass within other seagrass habitats	1%+

Status & Threats

RSZ seagrasses are mainly found in intertidal and shallow waters (<10 m), but have been observed down to 54 m. So far, 10 of the 12 species known from the Red Sea region have been recorded: *Enhalus acoroides, Halodule pinifolia, H. uninervis, Halophila decipiens, H. ovalis, H. stipulacea, Cymodocea rotundata, C. serrulata, Thalassia hemprichii, and Thalassodendron ciliatum*[32]. Shallow meadows tend to be diverse, but, deeper than 4 m, are often monospecific meadows of *H. stipulacea, T. hemprichii* or *T. ciliatum.*

Seagrass meadows are important for carbon sequestration, as a food source for Dugong, and Green turtles, and as foraging or nursery area for other priority species including coastal rays. The most common taxa, *Halophila spp.* and *Halodule spp.*, which are fast-growing pioneer species, are the preferred food for dugong and Green turtles. *Cymodocea* spp., a secondary food source for Dugong, is also abundant. Also relatively common are *Thalassia hemprichii* and *T. ciliatum*, which, with their highly developed root systems, contribute most to substrate stabilization and carbon sequestration.

Seagrass habitat maps that have been derived from satellite data, are unreliable because seagrass does not have a clearly identifiable signature from such data. We are working to improve habitat maps with widescale spot-checks and comprehensive in-water surveys at priority areas (Figure 5). For now, the best available estimate of total seagrass area, comes from a model of seagrass suitability combined with spot check data, which indicates that there is ~97 km^2 of seagrass habitat, but much of that is very sparse (cover <5%), only less than a third has >20% cover, and just 2.8% is dense (>50% seagrass cover).

All seagrass species in our area are classified as "Least Concern" by IUCN. However, *H. pinifolia* and *E. acoroides* are globally decreasing, and the overall areal extent of global seagrass has declined by 19% over the last century[33]. Generally, seagrass meadows are threatened by direct losses from coastal development or by water quality degradation, particularly increased turbidity. So far, known impacts of development within RSZ on seagrass have been negligible - only affecting small areas of sparse seagrass habitat. Other potential impacts, include physical damage from fishing activities including anchoring, and from heatwaves due to climate change, but the extent of those is unknown.

Enhancement Efforts

TRANSPLANTING

Red Sea seagrass propagate mainly through vegetative growth, which makes transplanting the most viable enhancement strategy, especially for fast growing species such as *Halophila* spp. and *Halodule* spp., which are the key food resources for Dugong and Green turtles. Transplanting activities are, however, very resource intensive and therefore expensive to scale up. The key for this to be successful is to identify suitable habitat to transplant into - areas which lack seagrass, but with high potential for survival and outward expansion. Unfortunately, there have not been previous publicly available efforts to enhance Red Sea or comparable seagrass habitats at scales that are suitable benchmarks. Therefore, estimated gains from this activity have a high degree of uncertainty, but that uncertainty will reduce as mapping and transplant pilot studies progress.

NURSERIES

Growing seagrass from seeds to later outplant is theoretically possible, but seeds have only been recorded for only one Red Sea species, *Enhalus acoroides*, which is also one of the rarest species in the RSZ. Hence, unless other larger *E. acoroides* meadows are found, we think there is insufficient source material to prioritize this approach.

Data Sources & Indicators

Seagrass habitat suitability models were built using ground-truthing data collected from 2017 to 2022, and using depth and slope as predictors in the final model. These models combined with ground-truthing data provide an estimate of current areal coverage and density of seagrass meadows. The model was limited to the Al Wajh lagoon, where we believe the great majority of existing and potential RSZ seagrass habitat is.
Information on seagrass is being improved by focal surveys and mapping of priority areas: <10 m deep habitat, at or near areas where seagrass have previously been recorded, and which are known foraging areas for priority species (Figure 5). So far, 58 km² of the ~130 km² priority areas have been surveyed. Data from this effort will be used to train AI tools to classify high resolution satellite images to produce seagrass layers for the whole lagoon (i.e., polygons of seagrass presence/absence, % cover classes, and species communities). This effort will later be expanded into other areas.

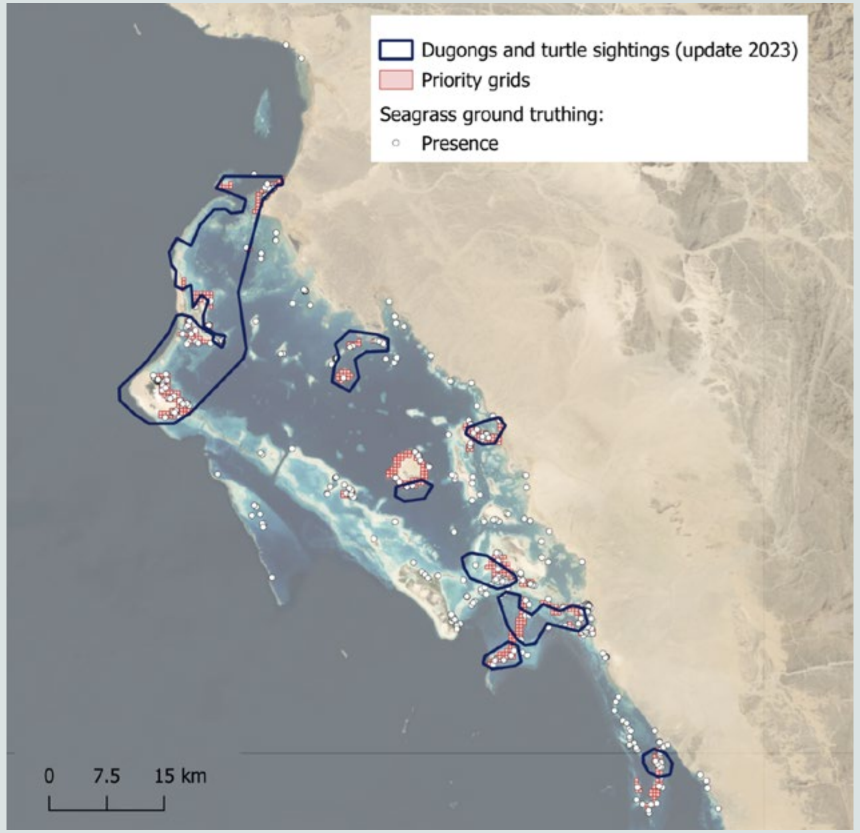


Figure 5 | Priority areas for in-situ seagrass mapping

Monitoring sites within priority areas or areas targeted for transplant pilots will provide information on recovery in areas where seagrass have been extracted from, and growth, expansion and survival in areas where seagrass are transplanted into, as well as possible degradation due to natural impacts.
Indicators are total seagrass (areal extent x mean cover) in high quality seagrass habitats (70% of score) and other seagrass (30%). High-quality habitats include meadows of *Halophila* spp. and *Halodule* spp. (preferred food source of Dugong and green turtles) with >25% cover, and dense meadows of any species (>50% coverage), since dense meadows provide significant ecosystem services (substrate stabilization, carbon sequestration, water quality enhancement).

SIIG: REEF FISHES

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Establish large areas closed to fishing · Protect spawning aggregations · Fishery management	· Total reef fish biomass · Total biomass large (>25cm) fishes · Encounter rates with rare and vulnerable species	113%

Blackfin barracuda

Status & Threats

RSZ reef fish communities are very diverse, with 413 species recorded in our surveys to date (and potentially up to 1,000 reef associated species in Red Sea region). Important species, with notable populations in our area, include the Humphead wrasse and Bumphead parrotfish, considered, respectively, endangered and vulnerable on the IUCN Red List. Other threatened species, including two species of coral grouper, are regularly encountered, although large adults are rare. Highest reef fish biomass is usually found on outer reef walls and offshore reefs, and is lower within the lagoon, particularly in highly turbid habitats. Planktivores, including schooling fusiliers and anthias, are extremely abundant on many outer reefs, indicative of a productive ecosystem capable of supporting abundant marine life.

The primary impacts to reef fish communities are from commercial fishing. There are more than 750 Saudi fishers in the Umluuj and Al Wajh governates[34], but the vast bulk of fishing within RSZ is by foreign labor operating on small boats. The extent of that fishing is considerable, with more than 1,000 'active fishing' vessels registered at RSZ coastguard stations[35]. Statistics from the Fisheries Sector of the Ministry of Environment, Water and Agriculture indicate that approximately 5,000 fishing licenses have been registered in the region, stretching from Duba in the north to Umluj in the south. The number of foreign labor fishermen reached 2,811, while the number of Saudi fishermen reached 2,190. The number of registered boats reached 1,400, undertaking approximately 25,000 fishing trips annually within the RSZ.

Although there are around 80 km^2 of complex coral reef habitat and a much larger area of shallow fishable habitat, fishing intensity is enough to have considerable impacts. Results from the 2021-22 RSZ baseline surveys showed that reef fish biomass across the RSZ area was around a third of that on comparison remote and very lightly fished reefs in the Red Sea region. That scale of depletion is consistent with many studies from across the world, which have consistently shown that even moderately intensive fishing causes large declines in reef fish biomass, often to between a quarter and a half of pristine states[36–38].

Although a wide range of species are present on RSZ reefs, the most vulnerable and targeted species such as large-bodied grouper and snapper are not abundant.

Enhancement Efforts

ESTABLISH LARGE AREAS WITH NO EXTRACTIVE FISHING

The proposed Al Wajh Lagoon fishery management area (Appendix A) would prohibit extractive fishing within nearly 2,000 km^2 of shallow habitat. This is around half (47%) of all shallow (<30 m deep) habitat, and 52% of all coral reef habitat within the Red Sea zone. Any prohibition on fishing at that scale would have dramatic conservation benefits.

Large and well managed marine protected areas (MPAs) elsewhere in the world with strict restrictions on fishing generally have 2-4 times the biomass of comparable unprotected areas, with much larger differences for the most heavily fished and vulnerable taxa – including larger grouper, snapper, and emperor which can be up to 10 times as abundant within effective reserves[39]. As many reef fish are long lived, achieving that scale of gains requires sustained protection. Typically, clear positive impacts are evident after 3-5 years of protection, but 10-15 years or more are required for fish communities to fully recover to natural states[40].

PROTECTION OF SPAWNING AGGREGATIONS:

Some reef fishes, including several highly targeted grouper, emperor and snappers, gather in large numbers to spawn at specific places and times of year. These 'spawning aggregations' are highly predictable, and therefore vulnerable to overexploitation. Seasonal closures at aggregation sites will protect these fishes at a vital period in their lifecycle, ensuring the continued supply of larvae and juvenile fishes to sustain future generations. Some of those larvae are exported long distances from the spawning sites[41]. Therefore, protecting these spectacular natural events can also benefit fisheries in distant areas, and, following recovery, may be especially important for species that are heavily targeted and depleted elsewhere in the region.

INFORMED ADAPTIVE FISHERY MANAGEMENT:

Active adaptive management of fisheries within a broader managed area context or otherwise will benefit fish populations, improve fishery sustainability, and potentially also optimize fishery yields. This could involve restricting certain gears or total effort, and to be effective requires high quality information on catch rates, gear selectivity, and catch composition. Building that information base will require a dedicated catch enumeration program involving inspections and interviews with fishers returning to ports at the end of fishing trips, along with other collaborative programs to gather fishery information.

Data sources & Indicators

Reef fish baseline monitoring was completed in 2021-22, for which fish communities were surveyed at 360 sites (280 Red Sea Destination, 80 AMAALA, Figure 6) using underwater visual surveys of 50m transects. This is the most widely used reef fish survey approach in the region and globally. 80 to 120 of those sites are resurveyed every year. Use of a statistically rigorous survey design, with sites randomly located within habitat strata encompassing all complex coral reef habitats in <20 m of water, ensures that sites are unbiased and representative.

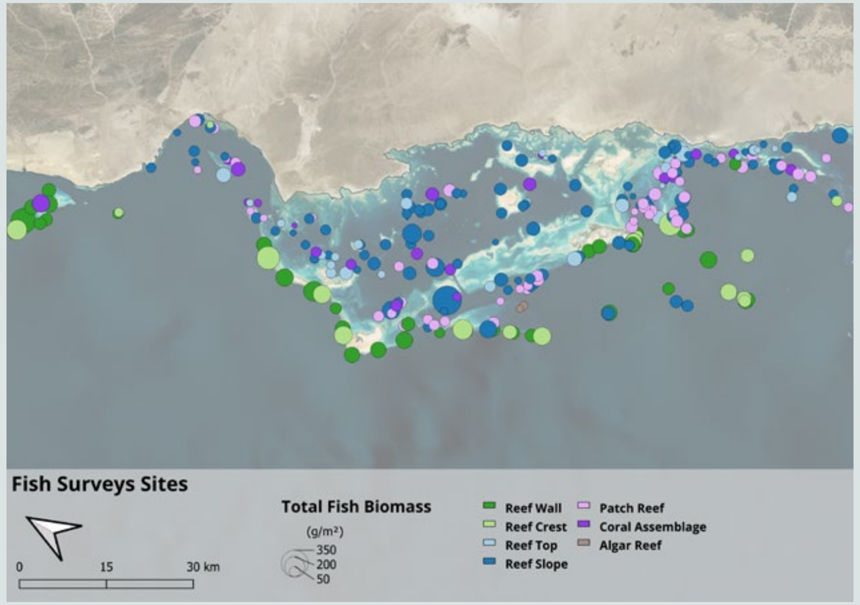


Figure 6 | Baseline fish & Habitat survey sites in The Red Sea Destination.
Colors represent different habitat strata and bubble sizes represents estimated total biomass.

Selected indicators are **total fish biomass** (estimated wet weight of fishes per standard survey, reflecting both abundance and size) and which is the most widely used measure of reef fish population status; **large fish biomass** (biomass of the larger-bodied fishes that are most vulnerable to fishery impacts); and **encounter rates with rare and vulnerable species** (Bumphead parrotfish, Humphead wrasse, large-bodied grouper, emperor, and jack) which is best feasible measure of the abundance of species with outsized ecological roles, and which are depleted across much of their range. These 3 indicators are weighted equally (each 1/3 of overall reef fish status score).

SIIG: SEA TURTLES

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Sea-cliff barriers · Nest shading and relocation · Nesting beach improvement · Prohibition on netting and access controls · Rehabilitation of sick and injured turtles	· # Green turtle hatchlings · # Hawksbill turtle hatchlings	12%


Green turtle hatchling

Status & Threats

Two species of sea turtles nest in RSZ: Hawksbill and Green turtles. The total amount of nesting varies from year to year, but on average we record around 213 Hawksbill nests and 454 Green nests per year across 50 islands and a few sections of mainland coastline. This corresponds with an estimated breeding population of around 234 Hawksbill and 231 Green females utilizing RSZ beaches, with ~1/3 of those nesting each year.

The most important beaches are at Waqadi and Breem, among the most important turtle beaches in the entire Red Sea. Both species nest on both islands, but Breem is especially important for Greens, averaging 265 nests a year, largely concentrated within 6 km of coastline, and Waqadi most important for Hawksbills, averaging more than 60 Hawksbill nests and nearly 50 Green nests every year on its 4 km of beaches.

Although sea turtles are abundant within RSZ, they may face mitigatable threats. These include risk of boat strikes and accidental entrapment in fishing gear, as well as the accumulation of marine debris on preferred nesting beaches, which hinders nesting and reduces hatchlings' ability to successfully emerge and reach the ocean. For reasons that are not fully understood, Hawksbill turtles in RSZ and elsewhere sometimes suffer from 'floating syndrome', preventing them from submerging, making them vulnerable to dehydration and starvation, and increasing the risks of boat strikes. Fortunately, this is a treatable condition, and between 2021 and 2024 six turtles with this condition were successfully recovered and rehabilitated from RSZ waters. Turtles also face risk of injury or death due to the topography of the key Green turtle nesting area on the southwest of Breem Island. These intensively used beaches are broken up by short section of low (~1 to 1.5 m) sea-cliffs which present a hazard to female sea turtles attempting to return to sea. Since 2019, there have been 10 known mortalities of Green turtles caused by falls from these cliffs[42].

Climate change also poses a threat to sea turtle populations. Sea turtle hatchling gender is determined by nest temperature, meaning that global warming may cause population feminization, i.e., production of hatchlings that are heavily female-skewed. Though unknown whether this is impacting RSZ[43], in some other parts of the world hatchlings have become overwhelmingly female dominated with indications that adult populations now have too few males to sustain sea turtle breeding success[44].

Enhancement Efforts

TURTLE BARRIERS AT BREEM SEA CLIFFS: In 2024, we established protection barriers around one of the Breem sea cliffs, which have been completely successful in preventing turtles from straying into hazardous areas, ensuring they safely return to sea. This approach promises to dramatically reduce rates of injury and mortality for Green turtles at Breem, the species most vulnerable due to their size.

RECOVERY & REHABILITATION of sick and injured turtles. A partnership with SHAMS veterinary hospital and establishment of improved sea-turtle holding facilities at the RSZ regeneration center will ensure optimal outcomes for turtles suffering from floating syndrome and other conditions recovered within RSZ waters.

NEST SHADING Trials of nest shades 'Qubba' (Figure 7) have shown success in reducing nest temperatures and temperature spikes sufficiently to improve hatching success during temperature peaks and may also increase production of male hatchlings. Work that is underway in the region to determine pivotal temperatures for sea turtle sex-determination will guide future efforts to ensure gender balance of hatchlings from prime nesting areas.

NEST RELOCATION involves relocating newly-laid nests to locations with higher expected hatching success. This includes doomed nests, laid below high tide, and nests in areas with consistently low hatching success.

BEACH DEBRIS CLEANUP In early 2024, we removed 45 tons of long-accumulated debris from nesting beaches on Breem and Waqadi. The quantity and size of debris on some beach areas (Figure 7) was likely reducing nesting success, stressing nesting turtles, and hindering hatchlings' attempts to reach the ocean. This clean-up effort and future periodic removal will improve nesting and hatching outcomes.

Figure 7 | Breem sea turtle barriers, nest-shading pilot, and pre-cleanup beach legacy debris

FISHERY MANAGEMENT AND ZONING: The establishment of large areas with no-netting, and regulation of boat speeds and access in areas where turtles are most vulnerable would substantially reduce risks of injury or mortality from incidental entrapment and boat strikes. To this end, speed restrictions were established in several places within the RSZ in 2025.

Data Sources & Indicators

All significant nesting beaches in RSZ are surveyed annually, with most important nesting beaches visited at least once a month through nesting seasons. For every track, surveyors record information including species and outcome (nest, false crawl, etc.). Hatchling success surveys provide information on clutch size and proportion of eggs successfully hatched and emerged. Collectively, these data allow us to estimate total **production of Green and Hawksbill hatchlings.** Number of hatchlings reflects both the number of mature female turtles and the quality of nesting beaches, as well as the success of other efforts to improve hatching outcomes such as nest shading and relocation. Critically endangered Hawksbills are weighted more highly (60%) than Green turtles, which are not endangered (40%).

SIIG:
COASTAL RAYS AND SHARKS

S.I.I.G MODEL

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Establish large no-fishing area(s) · Strengthened fishery management · Protection of critical habitats	· Abundance of priority species per standard survey · Abundance of other species per standard survey	72%

Spotted eagle ray and fusiliers

Status & Threats

Sharks and rays tend to have long life spans and low reproductive rates, which make them highly vulnerable to depletion from any degree of unnatural mortality. As a result, they are among the most threatened groups of animals on earth[45].

So far, 26 elasmobranch species have been recorded in RSZ waters, the great majority of which are considered threatened. These species can be loosely classified into wide-ranging species (e.g., Tiger sharks, Hammerhead sharks, Whale sharks and Manta rays) that periodically utilize our waters, reef-associated sharks (e.g., Blacktip reef sharks, Whitetip reef sharks, and Nurse sharks), and coastal rays (e.g., stingrays and guitarfish). Our conservation focus is on the latter two groups, as we can have only limited impacts on the most wide-ranging species.

The Al Wajh lagoon is of particular importance for juvenile rays, as it contains important nursery habitat for high priority species. These include the critically endangered Halavi guitarfish (*Glucostagus halavi*) and the endangered reticulate whipray (*Himantura uarnak*), which both have year-round residency at islands such as Quman and Al Osh Al Sharqi. Reflecting this conservation significance, the Al Wajh lagoon was declared as an Importance Shark and Ray Area (ISRA) by IUCN in 2023[9].

Figure 8 | *Coastal sharks and rays of high conservation concern in the Al Wajh lagoon*
Top row (L to R): Eagle ray, Halavi guitarfish, Lemon shark;
Bottom row (L to R): Whitetip reef shark, Reticulate whipray; Mangrove whipray

There is considerable evidence that sharks, and some rays, are depleted across much of the Red Sea region, including within Saudi Arabian waters[46–48]. Although sharks and most rays are legally protected in Saudi Arabia, they are still vulnerable to fishery impacts, due to imperfect compliance and, probably more importantly as bycatch. Juvenile sharks and rays are particularly vulnerable to incidental capture in gillnets, as their shallow nursery habitats tend to be more heavily fished by this method. Mature females – the highest conservation priority - are also vulnerable, and recently a large pregnant Halavi guitarfish was caught in this way. Fisheries also impact elasmobranch populations by depleting the fishes they prey on.

For elasmobranch species, such as the Halavi guitarfish with nursery habitats in shallow nearshore waters, there is potential for coastal and island development to fragment or disrupt their key habitats. Managing that risk requires high quality information on where these locations are and how they are used.

Enhancement Efforts

ESTABLISHMENT OF LARGE NO FISHING ZONES

The proposed AWL Fishery Management Area would fully protect sharks and rays from fishing in around 1,900 km^2, including ~120 km of continuous outer reef habitat (Appendix A). That level of protection at that spatial scale, achieved through closed areas or other fishery regulation, provides scope for major recovery, to levels that are only normally seen at highly remote and unfished areas which have been shown to have 3 to 10 times higher shark abundance than comparison fished areas[49].

PROACTIVE FISHERY MANAGEMENT AND ENFORCEMENT

In addition to fully closing some areas, other benefits would arise from improved enforcement of the existing protections for sharks in Saudi Arabia, and from restricting the use of gears such as gillnets, which has been associated with higher abundance of sharks elsewhere in the world[50].

PROTECTION OF KEY HABITATS

Shallow water nursery habitats within the RSZ, such as soft-bottom areas, seagrass beds, and mangroves, are critical for the early life stages of shark and ray species, and several species will spend significant time within these habitats. Identification and protection of these areas is a vital component of their conservation, which allows population gains to be sustained and reinforced by high recruitment success.

Data Sources & Indicators

We have two sources of data for sharks and rays. Baited Remote Underwater Video (BRUV) surveys, which are widely used to assess abundance, diversity, and distribution of sharks and rays. Our 2024-5 BRUV baseline for the Red Sea Destination involved around 300 deployments, and we aim to sustain a similar level of effort in coming years. In addition, species and number of elasmobranchs sighted during underwater reef fish visual surveys also provides a consistent dataset of observations per unit effort that we will track through time.

Indicators of elasmobranch status are **relative abundance of priority species** (60%) and **other species** (40%) from standardized surveys. Priority species were selected based on key biological and conservation criteria, including IUCN Red List status, residency patterns, and habitat associations. Species of higher conservation concern (e.g., Critically Endangered, Endangered, or Vulnerable), those using the RSZ as a nursery or with strong ties to specific, localized habitats, were prioritized. Based on these criteria, the top three rays (Halavi guitarfish, reticulate whipray, and mangrove whipray) and the top three sharks (lemon shark, blacktip reef shark, and whitetip reef shark) were identified as priority species.

SIIG:
MARINE MAMMALS

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Prohibit gillnetting in key areas · Reduced disturbance in key habitats	· Encounter rates in standardized surveys · Reproductive success	24%


Indo-pacific bottlenose dolphin

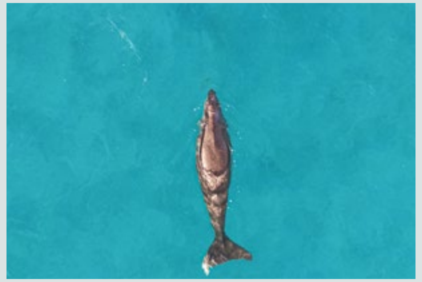
Status & Threats

Nine marine mammal species have been observed in The Red Sea destination and AMAALA waters. The two species of greatest conservation significance are the vulnerable and ecologically distinctive Dugong (*Dugong dugon*) and the endangered Indian Ocean Humpback dolphin (*Sousa plumbea*). Spinner dolphin (*Stenella longirostrus*), Common and Indo-Pacific Bottlenose dolphin (*Tursiops truncatus*, *T. aduncus*), and Risso`s dolphin (*Grampus griseus*), are also seen. Species seen on only few occasions are Pantropical Spotted dolphin (*S. attenuata*), False Killer whale (*Pseudorca crassidens*), and Orca (*Orcinus orca*).


Humpback dolphin


Bottlenose dolphin


Spinner dolphin


Dugong

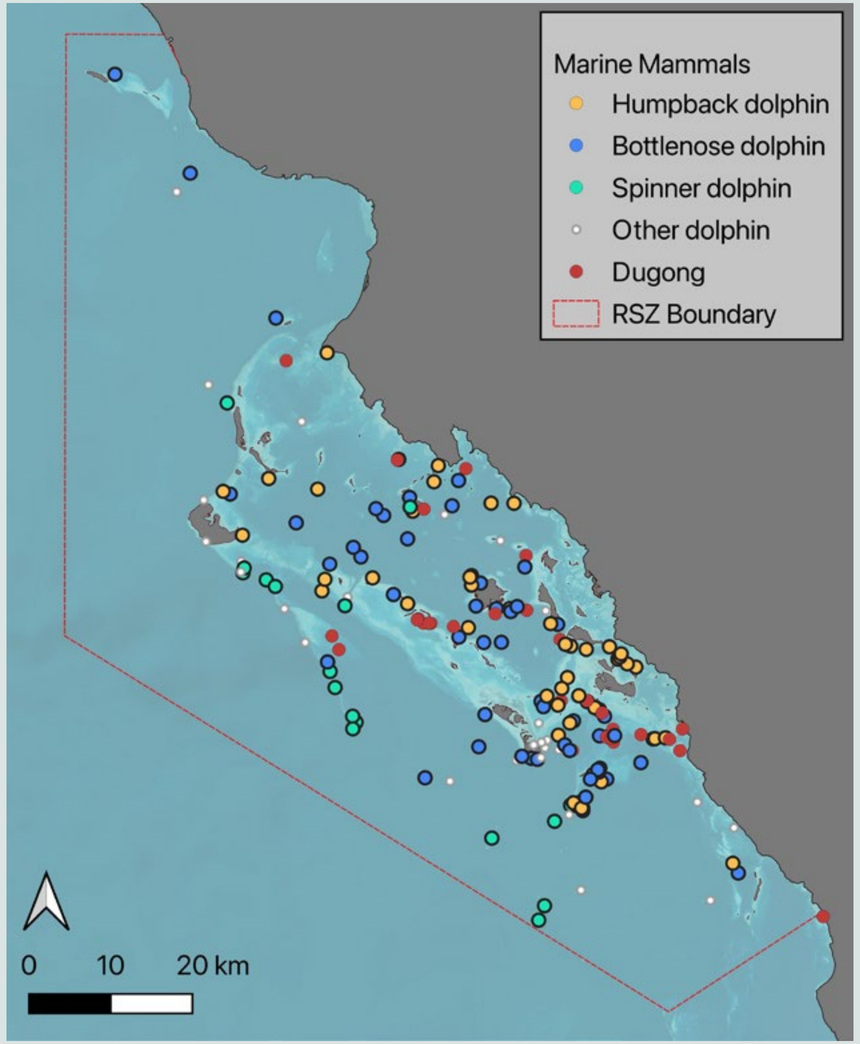


Figure 9 | Distribution of the commonly encountered marine mammals.

Spinner, Bottlenose, and Indian Ocean Humpback dolphin, and Dugong all appear to have resident populations within and around the lagoon. Indian Ocean Humpback dolphin and Dugong predominantly use shallow habitats, often close to shore and therefore with greater exposure to boat traffic and to fishing, especially netting. These species likely have small populations within RSZ: probably 20 or fewer Humpback Dolphin; and unknown but probably few Dugong. This makes them inherently more at risk than species with large populations[51,52]. Spinner dolphins are generally observed outside the lagoon, frequently in sheltered habitats behind the offshore 'al Jadir' reef. Bottlenose are more commonly observed within and south of the lagoon. The frequent presence of calves in those areas indicates successful reproduction for these species. Although each species has unique behaviors, habitat preferences, and social structures, there are similarities in threats and how those can be managed. All species are vulnerable to injury or death from boat strikes, which can be mitigated by speed and access regulations. More importantly, frequent boat presence in key habitats, disrupts behaviors such as feeding, resting, mating, and caring for offspring. This can displace marine mammals from preferred habitats, decreasing reproductive success[53,54] and otherwise impacting their wellbeing, and could even cause animals to relocate out of our waters completely. A major threat for marine mammals is entrapment in active, lost or abandoned fishing gear, particularly gillnets. This is likely the main cause of population declines of Red Sea Dugong in recent decades[55]. Overall, the combination of lethal and non-lethal impacts very likely has large cumulative impacts on our populations. As such it is critical to identify and carefully manage the key areas for each species.

Enhancement Efforts

REDUCTION OF DISTURBANCE IN KEY HABITATS

The 2025 establishment of 7 conservation go-slow areas in the RSZ was an important first step to reducing risk of mortality and disturbance for marine mammals. Further implementation of go-slow and no-access zones in areas essential for mating, calving, and nursing can be expected to increase production and survival of calves[56], and ultimately adult populations[52]. Spatial management strategies will have to be adaptive with flexibility to identify, add or amend areas important to marine mammals[57]. This adaptability is particularly important given that we still do not fully understood the complexity of habitat use by marine mammals in our area. Adoption of best practices in the presence of marine mammals will also reduce avoidable disturbance to marine mammals.

PROHIBITION ON NETTING IN KEY HABITATS

The proposed fishery management area (Appendix A) would prohibit netting in much of the Al Wajh Lagoon, which includes most of the marine mammal hotspots. This would greatly reduce the main threat to Dugong and has proven to increase dolphin populations elsewhere[58]. Controlling fishing may also lead to higher abundance of fish species that dolphins feed on.

Data Sources & Indicators

Two types of systematic boat-based surveys are conducted: large-area line-distance sampling of all species; and targeted surveys for Humpback dolphin and Dugong. In both cases, data is gathered on species, number of individuals, behavioral status, and demographic composition. Cetaceans can be photo-identified based on their distinctive dorsal fins, enabling individuals to be followed over time (Figure 10).

Figure 10 | *Example of photo identification, showing three unique humpback dolphins individuals.*

These surveys therefore allow us to not only generate standardized encounter rates, as proxies for relative abundance, but also to improve our habitat use, behavior, and reproductive success (from number of calves encountered) over time to estimate actual population sizes.

Indicators are standardized **encounter rates**, weighted 60% for **priority species** (Humpback dolphin and Dugong) and 40% for other dolphin species (Bottlenose and Spinner). We aim to also develop an indicator of reproductive success, based on calves successfully weaned per female, which would be a leading indicator of success of efforts to reduce disturbance in key habitats.

SIIG: ISLAND BIRDS

KEY ACTIVITIES	INDICATORS	POTENTIAL NCG BY 2040
· Eradication of invasive rodents from islands where now present · Nesting habitat creation or improvement	· Breeding populations · Breeding success	19%


Lesser crested tern chicks

Status & Threats

The RSZ, particularly the Al Wajh bank with its 92 islands, is a globally significant area for island bird conservation, which is recognized as an 'Important Bird Area' by Bird Life International. This means that it is *globally important for bird conservation*, one of only 19 in Saudi Arabia with this designation for globally threatened species[10].

We prioritize 14 bird species that breed on RSZ islands, based on their breeding population size and distribution and their conservation significance, including whether they are endemic[59]. 87% of the islands have had at least one of those species breeding on them over the last 3 years, and several islands have many species - Breem has most, with up to 12 breeding species using it in any year. Collectively, nearly 30,000 breeding pairs nest and rear young on these islands every year. For several species, these include significant portions of the entire global breeding population, including Sooty falcon (2-3%), Crab plover (5%), Sooty gull (17%–35%), White-eyed gull (15%), Bridled tern (1%), White-cheeked tern (4%), and Lesser crested tern (2%). Two species are considered threatened the Sooty falcon and the Crab plover, regionally endangered and vulnerable respectively[60]. However, for several other species, global and regional population estimates are quite poor, and they are potentially more vulnerable than has been recognized.

Island bird species nest almost totally on the ground, on sandy and vegetated beaches or under rocks or in crevices. The greatest potential threat to their populations is likely from invasive predators such as rats, which prey on chicks and eggs. Comprehensive surveys of Al Wajh islands in 2023 and 2024 identified presence of rats on 3 islands, and mice, which can also be detrimental to birds, on 9. Cats have been seen infrequently but are considerably easier to remove than established rodent populations.

Other threats and limitations include, some hunting and egg harvesting, such as hunting of falcons in mainland areas where Sooty falcon forage, entanglement in debris or fishing gear, disturbance during breeding season, depletion of seabirds' food base. Additionally, some species – such as Sooty falcon and Crab plover - have quite limited, and probably fully-utilized, suitable breeding habitats, constraining the ability of their populations to grow. For those and other species, impacts of coastal and island development that encroach on these habitats will have major impacts if not properly mitigated.

There is growing evidence that transfer of nutrients from offshore to nearshore environments by seabirds benefits coral reefs and other marine habitats near their breeding colonies[61]. Therefore, seabird recovery may have benefits for other marine conservation priorities.

Enhancement Efforts

RODENT ERADICATION

Rodent eradication is not straightforward but successful removal of these pests from other islands with large seabird populations has led to dramatic – 10-fold and greater - increases in seabird breeding populations[62–64].

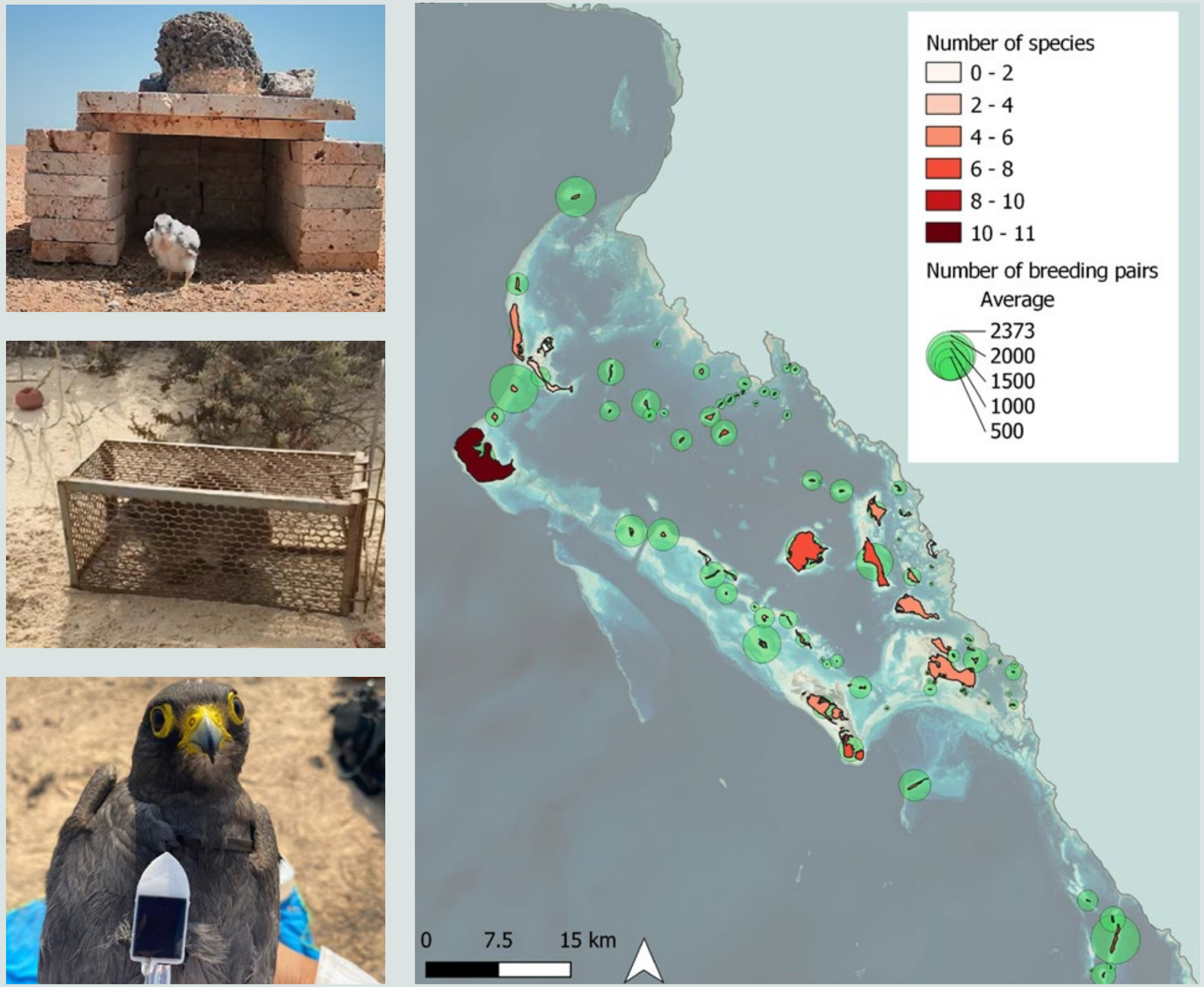


Figure 11 | *Seabird distribution at AWL; Sooty falcon chick and nest box; Rat trap on one of the islands , Tagged Sooty falcon.*

NEST BOXES AND NESTING HABITAT IMPROVEMENT AND CREATION

Where nesting habitat is limited, provision of artificial nest boxes or additional suitable habitat can substantially increase bird populations. Nest boxes have been successfully used to enhance population of falcons elsewhere[65], and initial results at RSZ islands have been promising, following establishment of 30 next boxes in recent years (Figure 11). Floating rafts have been effectively used to increase nesting habitat for terns in several locations[66–68]. Initial enhancement efforts will focus on these two species, but with potential to extend to other species with limited breeding habitat, such as Crab plover. Beach debris removal at key sites could also improve breeding outcomes and reduce accidental entanglement.

FISHERY MANAGEMENT

As seabird populations can be negatively impacted by fishing[69], there is scope for increases in breeding success and ultimately breeding populations if fisheries are restricted in areas where seabirds forage. Effects are difficult to predict, but it is likely that this would be beneficial to seabirds by ensuring there is sufficient prey-base for current and future populations. Restricting fishers (and others) access to islands during breeding seasons would also reduce disturbance to breeding pairs while their eggs are chicks are particularly vulnerable.

Data Sources & Indicators

Breeding bird populations have been surveyed annually since 2021. This involves counting and geolocating nests and, for colonial species, estimating total breeding pairs per colony. We also track breeding success from eggs laying through fledging for seven species. As breeding locations and population size are variable from year to year, the multi-year average we can now generate for 14 tracked species is a strong baseline. Other surveys track migration patterns and foraging areas, and utilization of nest boxes. Ringing of all Osprey and Sooty falcon chicks allows for assessment of population dispersion and recruitment.

Indicators are **breeding population** (number of breeding pairs for each of the 14 tracked species) and **breeding success** (number of fledglings produced per pair). Breeding success is an important leading indicator of future population trends, and likely highly related to success of conservation efforts including pest eradication, fishery management, and management of breeding sites.

The Roadmap to Achieving Measurable Conservation Gains

S.I.I.G MODEL

WHAT SCALE OF

conservation gains are possible?

05.

There are considerable differences among habitats and groups both in terms of predicted conservation gains (Table 3, Figure 12),

as well as in the strength of evidence available to make predictions. However, although any estimate of conservation outcomes 15 years ahead entails a degree of uncertainty, the actions described in sections above, all of which are already underway or planned, can feasibly achieve very large conservation gains – including exceeding the target of 30% net conservation gain (Table 3).

Goniopora coral

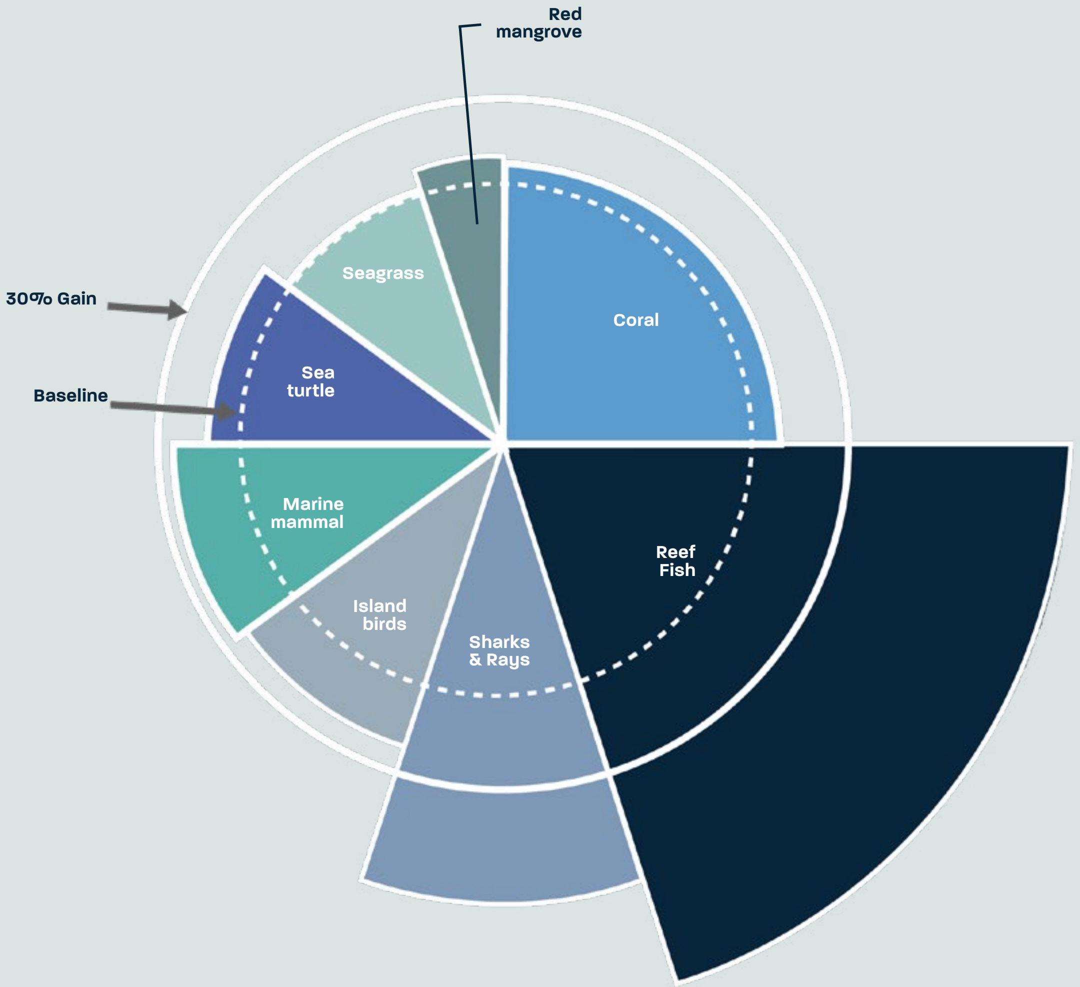
Table 03 | *Predicted net conservation gain (NCG) by group and overall. Predicted NCG per habitat or species group are detailed in Appendix B.*

Habitat or Species Group	Weight	Predicted BNG	Notes
Corals	**25%**	**5%**	Gains largely from restoration of fish herbivory within an FMA, which benefit corals, and from reduction of anchoring damage. Benefits from active restoration – coral gardening and propagation – could be dramatically scaled up in future with additional resources and from expected technological advances.
Seagrass	10%	1%	Scale of gains is highly dependent on proper site selection, expansion rate of transplanted seagrass and availability of resources for scaling-up. Pilot studies initiated in 2025 will improve scope for estimation and understanding of potential returns from scaling up these efforts.
Red Mangroves	5%	8%	Estimated gains are largely based on completed pilots, therefore made with good confidence. Major current limitation is availability of suitable restoration sites, which could be mitigated through geo-engineering.
Reef Fishes	20%	113%	Very high potential for recovery of fish populations within proposed AWL FMA and made with high degree of confidence based on comprehensive evidence of impacts of fishing and protection in coral reef environments.
Sharks & Rays	10%	72%	Their life-histories make this group extremely vulnerable to depletion, but also, therefore, with high scope for recovery from mitigation of their main stressor incidental capture as fishery bycatch. Large highly protected areas important for mobile species.
Sea Turtles	10%	12%	Significant gains are likely from underway or soon to be initiated interventions, including the Breem sea-cliff barriers, boat-strike management, restrictions on netting in key areas, nest relocation and shading, and turtle rehabilitation. Gain predictions are made with reasonable confidence and considered conservative.
Marine Mammals	10%	24%	Predicting rates of recovery is difficult, but there is scope for large gains from spatial management that minimizes disturbance in key habitats and reduces incidental capture in fishing nets.
Island Birds	10%	19%	A complex group, with pressures and opportunities varying by species and location. Very large potential gains from rat eradication, and from provision of nesting habitat. Recovery of prey base from fishery regulation may be important to sustain gains.
Overall NCG*		**37%**	

*[Note *] The overall NCG is calculated by combining the predicted NCG for each group with that group's weighting. For example, if the predicted NCG for sharks and rays is 72% and this group accounts for 10% of the total score, its contribution to the overall NCG is 7.2%= 72% x 10%. The overall NCG is the sum of these weighted contributions across all groups*

For species groups, the largest gains generally arise from *removing or reducing pressures* such as fishing and disturbance. Removing or minimizing those pressures allows populations to recover to something close to their pristine states. Those kinds of interventions can also be important for habitats – for example corals will benefit greatly from regulation of anchoring in reef habitats, and through recovery of herbivorous fish populations, tipping the competitive balance to favor corals over their competitors such as benthic algae.

However, major conservation gains for habitats typically require resource-intensive active enhancement, such as establishing nurseries and out-planting propagules, building artificial reefs or nesting habitat, eradicating pests such as rats, and relocation of sea turtle nests to more optimal locations. Estimates of net gain for these sorts of activities provided here (Table 3, Figure 12) are based on already underway or planned activities, but for most of these, the potential benefits are highly scalable, with potential gains being highly related to resources that can be committed. Additionally, even where it's currently prohibitively expensive to actively enhance habitats at very large scale, there can still be enormous value in focused enhancement of high-priority areas, such as coral reefs adjacent to tourism assets and seagrass areas that will improve foraging for Dugong and Green Turtles. Ongoing efforts will also lay the foundations for more cost-effective larger-scale conservation later, for example, as technology improves for coral production and outplanting[70].



Predicted Conservation Gain
overall by 2040 37%

Figure 12 | *Schematic of predicted Conservation Gain by 2040. Radius of slices represents predicted gains, and dotted circle represents initial baseline.*

Restriction of fishing has enormous potential to lead to dramatic recovery of impacted groups, including a more than doubling of reef fish indicators and similar scale of response for sharks and rays (Figure 3). Because fishing and protection effects on coral reef fish and sharks have been extremely well studied, with hundreds of studies from thousands of sites available, these estimates of dramatic gains are made with a high degree of confidence.

Strictly regulating fishing within large areas is also important for other groups. It will reduce accidental entrapment of marine mammals, birds and turtles, minimize disturbance and risk of boat strikes for Dugong, dolphin and turtles, reduce the amount of anchoring in coral reef habitats, increase availability of prey for dolphins and seabirds. Furthermore, by reducing or restricting fishers access to islands, it will also remove one of the most likely vectors for introduction of rats and other pest species to those islands and reduce disturbance to breeding seabirds when fishers camp or otherwise land on islands during the breeding season. It is also a key intervention for corals, as the restoration of ecological balance when herbivorous and other fishes recover favors corals over their algal competitors. Many of the largest predicted gains arising from area management require a high degree of compliance with regulations and will only accrue after several years of effective management. Achieving those gains therefore requires sustained commitment not only to management and enforcement, but also to the monitoring, reporting, and stakeholder outreach necessary to build and maintain broad support and resources for conservation actions.

CONCLUSIONS

The RSZ area is being developed for luxury tourism with much of its expected appeal derived from its relatively intact nature, and opportunities for immersive wildlife tourism.

Based on the current quality and diversity of marine habitats and species, and the scale of conservation gains that are achievable, there is clear potential for RSZ to become recognized not only as world-leading nature tourism destination, but also a globally significant conservation area.

For this to be realized, it is essential that development impacts are minimized, and, in some cases, there will be a need for compensatory mitigation to achieve no net loss of biodiversity or ecological values. Our calculations of net gain assume that impact reduction and mitigation do at least meet that standard. That will require sustained commitment during both development and operation phases, including careful and proactive visitor and wildlife tourism management.

From the conservation interventions outlined in this report, very substantial conservation gains are achievable and feasible for the RSZ marine realm, including meeting or exceeding our target of 30% Net Conservation Gain. However, this will not be achieved without effective prohibition of fishing across large portions of the RSZ, as would occur if the proposed Al Wajh Lagoon FMA is established (Appendix A). Other highly important and impactful interventions include limiting boat access and speeds in marine mammal resting, nursery and foraging areas; improving sea turtle nesting beaches including establishing additional barriers on Breem to guide nesting sea turtles away from hazardous areas; eradicating invasive pests from islands where they have become established and ensuring that biosecurity measures are sufficient to prevent future invasions.

CONCLUDING REMARKS *By* EHAB AL KINDI

Head of Red Sea Zone

destination but a continuous journey of learning, adaptation, and action. At Red Sea Global, we are demonstrating that luxury tourism and environmental stewardship can not only coexist but excel together. By embracing science, innovation, and collective responsibility, we are establishing a global benchmark for regenerative development.

We ***remain*** **firmly committed** ***to*** **transparency, accountability,** ***and*** **partnership.** ***We*** **warmly** ***invite*** **scientists, conservationists, local communities,** ***and*** **international collaborators** ***to join*** **us** ***in*** **safeguarding the Red Sea's unparalleled biodiversity** ***today*** **and** ***for*** **generations to** ***come.***

This report marks a significant milestone in our commitment to achieving a 30% Net Conservation Gain (NCG) by 2040, one of the most ambitious ecological restoration targets worldwide, and a testament to our responsibility to protect the unique biodiversity of the Red Sea Zone. Over recent years, we have developed our signature SIIG Model, a science-driven framework that guides our pathway to this goal. Through comprehensive baseline surveys, rigorous fieldwork, and advanced ecological analysis, we have established a robust scientific foundation that now shapes every strategic and operational decision. These insights guide the design and implementation of targeted conservation and enhancement programs for the species and habitats that matter most. Together, these efforts ensure that our marine ecosystems do more than persist, they have the opportunity to recover, strengthen, and flourish for generations to come.

To support this mission, we have developed detailed conservation gain metrics that allow us to quantitatively predict ecological improvements, prioritize interventions, and optimize resource allocation. Coupled with our long-term monitoring programs, these metrics enable us to measure progress transparently and refine our strategies to deliver the biodiversity outcomes we aspire to achieve. The roadmap set out in this report is both ambitious and achievable, provided we maintain the dedication, innovation, and collaboration that have defined our work to date.

Biodiversity conservation is not a fixed destination but a continuous journey of learning, adaptation, and action. At Red Sea Global, we are demonstrating that luxury tourism and environmental stewardship can not only coexist but excel together. By embracing science, innovation, and collective responsibility, we are establishing a global benchmark for regenerative development.

We ***remain*** **firmly committed** ***to*** **transparency, accountability,** ***and*** **partnership.** ***We*** **warmly** ***invite*** **scientists, conservationists, local communities,** ***and*** **international collaborators** ***to join*** **us** ***in*** **safeguarding the Red Sea's unparalleled biodiversity** ***today*** **and** ***for*** **generations to** ***come.***

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APPENDIX A.

Proposed Al Wajh Lagoon Fishery Management Area

07.

The proposed Al Wajh Lagoon Fishery Management Area (AWL FMA) encompass the bulk of waters within The Red Sea Destination – totaling around 5,000 km2 of marine habitats. Most critical for conservation is that extractive fishing will be largely or entirely prohibited in conservation priority zones that encompass almost 1,900 km^2 including 46.9 % of all shallow (<30m) habitats and 52 % of coral reef habitats.

The proposed design of the managed area includes a single continuous conservation priority zone encompassing outer reefs and much of the lagoon (Figure 13), allowing for substantial and broad recovery. It includes most key habitats for sea-turtle, dugong, and dolphin. Netting would be prohibited in a few additional areas, mostly in places which are especially important for vulnerable turtles and marine mammals, with restrictions within those areas intended to reduce risk of bycatch and entanglement. The remainder of the FMA will promote well-managed and sustainable fishing over large areas, including the areas closest to human population centers of Umluj and Al Wajh.

The boundaries of the conservation priority zones were developed based on the wealth of information gathered during baseline surveys and ongoing monitoring since 2021. They are designed to be large continuous area that encompass sensitive and high biodiversity areas such as key coral reef habitats, sea turtle nesting beaches and endangered ray nursery zones.

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The process to establish the FMA is still ongoing, and it is possible the FMA will not be established or will take some other form. However, the current design is included for the purpose of predicting gains from a feasible and preferred scenario which includes large areas on which extractive fishing is prohibited. Whether such restrictions are achieved through establishment of an FMA or other management mechanism, something of this scale is a prerequisite for major conservation gains in the RSZ marine realm.

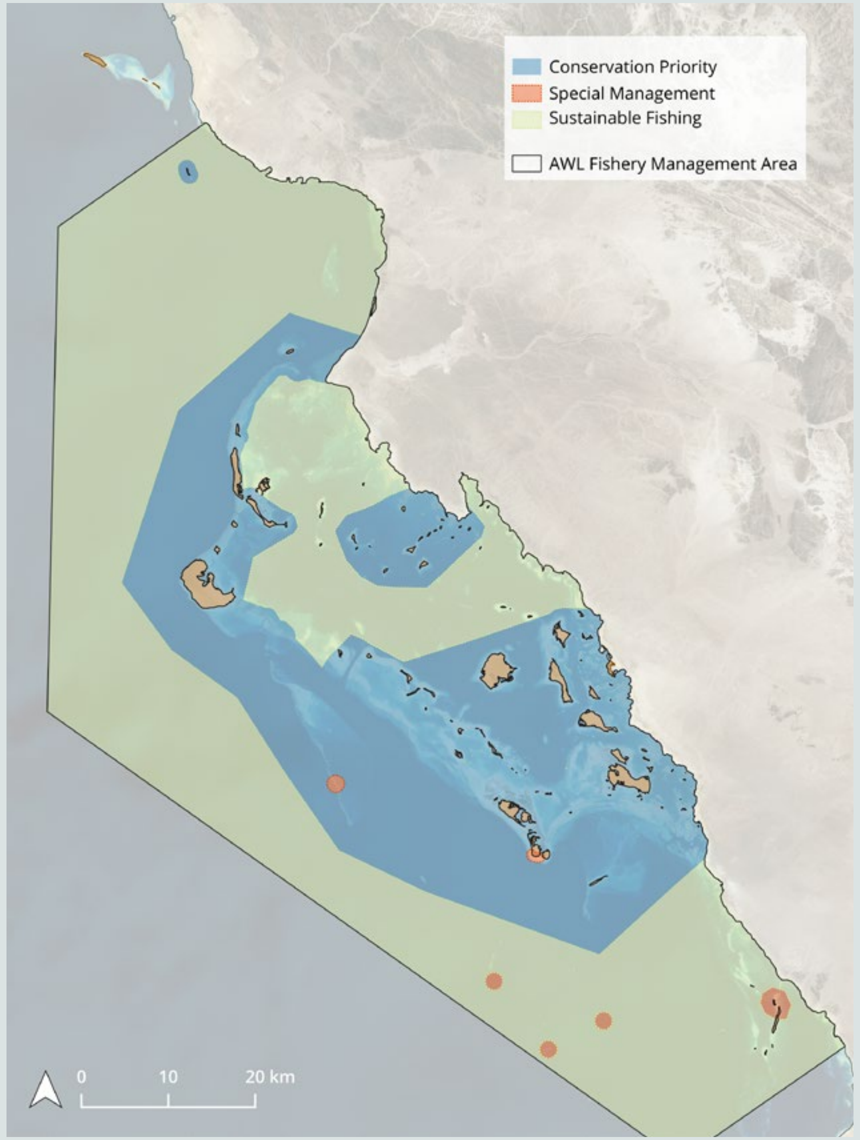

Figure 13 | *Proposed Zoning Al Wajh Lagoon FMA*
Extractive fishing would be prohibited in conservation priority zones; and lay-netting prohibited in special management zones. Fisheries would be supported and managed to optimize value in sustainable use areas

APPENDIX B.

Conservation Gain Prediction Workings

08.

CORALS

Indicators are **Coral Cover** and **Coral Generic Diversity**

BASELINE CORAL POPULATION

There are an estimated 81.5 km^2 of complex, shallow (<20 m) coral reef habitat within the RSZ, averaging 16% coral cover, and therefore 13.0 km^2 of coral tissue. This domain (complex shallow reef habitat is the explicit domain for RSZ coral reef fish & habitat monitoring, and data from that program considered to be best feasible representation of status and trends of corals within the RSZ (i.e. including corals found in other non-coral dominated habitats and in deeper photic reef habitats).

ACTIVE ENHANCEMENT: LARVAL PROPAGATION AND MICROFRAGGING.

Net outcomes of outplanting small and juvenile corals based on assumptions about number of units that can be outplanted as well as their survivorship and growth. Calculations based on 3 types of corals with different growth rates, max size, and source (typically microfragging for massive corals, larval propagation for branching and tabular corals).

Table C01 | # Planned outplants, and presumed growth rates and constraints for 3 groups of corals.

Category	Outplants /yr 2025	2026-27	2028-33	2034-40	Survivorship (% yr^{-1})	Diameter Growth (cm yr^{-1})	Max Diameter (cm)	Surviving Coral in 2040 (m^2)
Plating *Acropora*	0	2,000	4,000	6,000	90	10	100	37,222
Bushy/corymbose *Acropora*	5,000	6,000	4,000	6,000	90	3	40	4,819
Massive *Porites lobata/lutea*	1,500	6,000	12,000	18,000	90	2	100	5,659
TOTAL (m^2)								47,700
Impact of larval propagation & microfragging on coral cover								0.37%

Total surviving coral cover from propagation and micro-fragging (47,700 m^2 of surviving coral tissue in 2040) is 0.37% of baseline RSZ coral (estimated above). Note that we do not include any gains from coral gardening and reef building, as the scale of those is insignificant at RSZ scale. Those are focused on specific high value areas only.

PROHIBITION ON ANCHORING IN CORAL REEFS AND DEVELOPMENT OF SMALL BOAT MOORING NETWORK

By far the largest number of small boat trips are by fishers, estimated at 25,000 trips yr[1]. We assume an average of 4 anchor deployments on coral reef habitats per trip. Both those estimates are uncertain, but number of fishing trips is consistent with estimates of number of active fishers and limited data on fishing trip within brief periods for which data is available - not presented here. Fishing trips are typically 2-3 day long and involve regular anchoring overnight. Hook anchors almost universally used are only effective in rocky habitats where corals are present. Therefore, 4 drops on coral reef habitats per trip is likely conservative. Mason et al[71] modelled the effect of mitigation of 1.17 strikes ha^{-1} day^{-1} on a coral reef would result in coral gains of 2.6 to 7.7% absolute cover (average 5.15%). If we assume 100,000 anchors per year, over 81.5 km^2 of reef, result is 0.04 drops/ha/day, 2.9% of Mason model value. Therefore, we assume same level of impact of mitigation (2.9% * 5.15%), i.e. 0.15% absolute coral cover, which is 0.74% proportional increase in current coral cover. Note this does not include anchoring from large vessels, but we assume those will always anchor on sand or on moorings.

FISHERY RESTRICTIONS TO RECOVER OF ECOLOGICAL BALANCE

Natural fish populations, such as are found within well managed MPAs, can be very beneficial for corals, as demonstrated in a recent global study using data from 468 sites in 30 MPAs[23]. From that study, well-enforced no-take MPAs had on average 8-19% higher coral than nearby unprotected reefs. As a conservative approach, we assume that highly protected zones (AWL FMA conservation priority zones) will have 10% higher coral cover by 2040, and partially protected zones (AWL FMA special management zones) will have one quarter of that effect (2.5%).

Table C02 | Estimated gain from different interventions depending on proposed area zoning.

Intervention & Impact	FMA Zone: Conservation Priority	FMA Zone: Special Management	FMA Zone: Sustainable use	Outside FMA
Restoration of ecological balance from fish population recovery in FMA	10%	2%	0	0
Moorings and no-anchoring	0% (already included in benefits from restricting fishing)	0.7%	0.7%	0.7%
Total Impact FMA and Anchoring	**10%**	**2.7%**	**0.7%**	**0.7%**
% RSZ Coral Reef Habitat	52.0%	0.6%	31.2%	16.2%
% Impact on RSZ Coral Cover	**5.2%**	**0.2%**	**0.23%**	**0.12%**
Impact of FMA & Anchor Management on coral cover				5.6 %

TOTAL PREDICTED BIODIVERSITY GAIN

Combined cover gain as percentage of RSZ coral is 5.6% (FMA & Anchoring) and 0.4% (Propagation & Micro-fragging) is **5.9%. If we assume no change in coral diversity, overall conservation gain score for corals is 4.7%.**

Note that increases in coral cover from coral propagation and microfragging are based on assumption that resources (money and staff) available for that work will be broadly similar to current levels. However, production of coral outplant units is highly scalable if additional resources are committed. In addition, they do not account for future technological or other improvements that could greatly improve scope for effective large-scale enhancement. Finally, they also do not account for increased natural recovery on reefs that have been actively enhanced, as could be the case if, for example, active enhancement of a degraded reefs nudges that reef into a state where recovery will tend to naturally accelerate (e.g. artificially increasing coral cover from very low levels may increase the cues that trigger natural settlement of coral larvae, and/or enhancement that increases structural complexity can also increase populations of fishes and other organisms that tend to be beneficial for corals (e.g. grazers).

RED MANGROVES

Indicator Is **Above Ground Biomass (AGB).**

BASELINE RED MANGROVE AREAL EXTENT AND AGB

Ground truthing data[72] were used to identify red mangroves areas within the RSZ. From there, areal extent was estimated from manual digitization of polygons on drone imagery acquired in 2023 with a Ground Spatial Distance (GSD) of 3 cm px^{-1}. The estimated total area of red mangroves from this is 380,000 m^2. Application of standard allometric equation for Indian Ocean Red mangroves (with height as independent variable)[73] to measurements of height and diameter made for 79 RSZ red mangrove trees in 2024, gives us an estimate of average above ground biomass (AGB) per red mangrove tree in the RSZ of 2 ± 0.25 kg of dry biomass. Maximum height measured was 235 cm, corresponding to a max. estimated AGB of 3.55 kg. The average density from same surveys was 1.6 ± 0.6 trees per m^2, yielding total estimated baseline dry biomass of RSZ red mangroves of 1,228 tons.

BIOMASS NET GAIN ESTIMATES

Based on parameters in table below, we assume 5.300 propagules planted every year from 2026, resulting in 4,010 mangrove plants established each year. With stocking density of 1.6 trees m^{-2}, no more than 38,400 red mangroves can be established in the available area. Therefore, including the 2,500 propagules planted in 2024, the total area available for out-planting will be fully utilized by 2033.

Biomass per tree in 2040 calculated from growth rates and allometric relationship in table below, and based on years since planting, and maximum size of 235 cm (3.55 kg dry weight), yields total AGB production of 101,058 kg from nurseries, pollination, and afforestation.

Table MA 1. | Parameters and constraints for estimating red mangrove conservation gain.

Parameter	Value	Calculation
Suitable planting area	24,000 m^2	Only two areas, both with existing red mangroves in vicinity, were considered for red mangrove enhancement, a fenced coastal site and the Quman tidal channel. Other areas suitable for red mangrove growth are committed to grey mangrove afforestation for compensation of development impacts. For the fenced coastal site, available planting area is estimated as follows: (1) Elevation between 0.05 and 0.16 m above LAT to match red mangrove areas with known >80% propagation success; (2) Excluding unsuitable (i.e., rocky) substrate; (3) limited to polygons following natural topographic features of the site. This resulted in 23,600 sq. m of area available for enhancement. For the Quman tidal channel, available area was estimated from (1) length of portions of the tidal channel with no red mangroves but close to existing red mangroves and (2) assuming an available corridor of 1 m for planting along those portions of the channel. This resulted in ~400 sq. m of planting area.
Propagules available	3,500 yr^{-1}	Based on propagules available from known sources in 2023 and 2024, with max. 70% of propagules collected from any tree to avoid affecting natural propagation of the source forest. This is a conservative estimate because it only counts propagules available in September (peak propagule production period) but additional propagules are available in other seasons.
Propagules available with pollination	5,300 yr^{-1}	Assume 10-fold increase in propagule production (20-fold increase in fruit-set occurred in 2024 pilot honeybee introduction study), and this implemented at areas that would otherwise have produced only 200 propagules (<6% of total natural production).
Propagule survivorship to seedling in nurseries	90%	Rates obtained in 2023 RSZ red mangrove nursery.
Propagule survivorship in nature	9%	Goldberg and colleagues 2017 study shows only 9% of *Rhizophora* propagules fallen from mother trees develop into seedlings[74].
Survivorship of out-planted seedlings	90%	>90% of seedlings out-planted in July 2023 (n=155) were still healthy in January 2025, and expected to remain healthy since survivability has not declined after 6 months from out-planting. More than 97% of seedlings planted in July 2024 (N=2,240) were still healthy 10 months after out-planting.
Density of red mangrove forest	1.6 trees m^{-2}	Mean density of trees in RSZ red mangrove forests surveyed in 2024.
Linear Growth Rate	17.9 cm yr^{-1}	Measured from 155 seedlings planted in July 2023.
Maximum AGB of mature red mangrove	3.55 kg	Biomass of largest red mangrove out of 79 randomly sampled (height 235 cm), biomass from standard allometric equation $W(kg) = 6*10^{-5}*h^{2.0124}$, where h is height in cm[73].

TOTAL PREDICTED CONSERVATION GAIN

AGB net gain of 101 tons described above is equivalent to **8.2% of biomass AGB.**

This is considered highly achievable, and in fact conservative. The main factor limiting gain is available space for out-planting and the estimate used here is for only two known areas and limited to optimal habitats. Additional areas are likely available and could be expanded by geo-engineering or potentially by biological habitat enrichment (i.e. habitat improvements that arise from e.g. out-planting seedlings to increase sediment retention).

SEAGRASS

Long term Indicators will be **area of seagrass habitat** considered either high-quality (70% of score) or low-quality habitat (30% of score).

High-quality habitats include meadows of *Halophila spp.* and *Halodule spp.* with >25% coverage – those being these preferred food source of priority species - and dense meadows of any species (above 50% coverage), since dense meadows provide higher ecosystem services – e.g., substrate stabilization, carbon sequestration, water quality enhancement. However, available data do not allow us to accurately estimate cover by species. Therefore, for purposes of estimating potential seagrass gain here, we consider high-quality meadows to be only those with >50% coverage.

BASELINE SEAGRASS AREA & QUALITY

Ground-truthing data were collected between 2017 and 2022 from rapid assessments and surveys done as part of EIAs and by RSZ-EPR team in 2021-22 across the whole RSZ. These data, from 1,300 ground-truthing points, were used to model seagrass distribution with 50 m-pixel resolution for the Al Wajh lagoon. In model development, depth and slope (obtained from LiDAR and drone surveys done in 2016), temperature, salinity, pH and oxygen (obtained from interpolation of CTD casts done by RSZ-EPR in the Al Wajh lagoon in 2021) were all included. Of those, only depth and slope were significant predictors.

This model was then used to generate a raster of seagrass suitability (0 to 1) based on depth and slope. Areas already occupied by following habitats were excluded from resulting raster: mangroves; coral reefs; sabkhas, sandy beaches, sparse terrestrial vegetation, low lying island, rocky beach, and sparse and dense mangrove layers, based on habitat maps generated in 2018[75].

The area covered by the RSG habitat map mangrove layers was excluded, even if inaccurate for mangrove classification, to remove saltmarshes that often were wrongly classified as mangroves in that map.

Spot checking of this raster, begun in 2024 (3,288 spot checks), showed that 90% of points where seagrass presence was confirmed has suitability values >0.25. Therefore, only raster pixels with values >0.25 were considered potential seagrass habitat (total = 325 km^2).

At pixels with values >0.25, 2.8% of the spot checks were confirmed to be dense seagrass (coverage>50%) and 27.0% were low quality seagrass areas (coverage ≤50%), and remainder did not have any confirmed seagrass (Table SG1). Therefore, if we assumed that the same distribution occurs in the entire potential seagrass habitat, then the total baseline seagrass habitat would be 96.9 km^2, with high-quality habitat of 9.0 km^2, and low-quality habitat of 87.9 km^2 (and nearly 70% of habitat having 20% or lower coverage, Table SG1). Multiplying the estimated area of seagrass in each % bin by the mid-point of the bin, gives total surface area occupied by seagrass plants of 6 km^2 in high-quality seagrass meadows, and 12.5 km^2 in low quality meadows.

Table SG1. | Confirmed seagrass cover from 2,233 spot-checks of predictive map raster pixels with seagrass likelihood of >0.25

Seagrass % cover class	% Spot checks	Area (km^2)
0%	70.17	
0.1 - 10%	13.39	43.5
10 - 20%	6.98	22.7
20 - 30%	3.44	11.2
30 - 40%	1.97	6.4
40 - 50%	1.25	4.1
50 - 60%	1.16	3.8
60 - 70%	0.8	2.6
70 - 80%	0.35	1.2
80 - 90%	0.27	0.9
90 - 100%	0.18	0.6

ESTIMATED TRANSPLANT RATES AND IMPACT

In April 2025, transplant pilots were completed, with ~74,000 individual seagrass shoots (in 650 units of variable size) planted over an area of 2,000 m^2.

Targeted seagrass for transplant efforts will include the species that had the highest success and expansion rates from transplant pilots, that were done with abundant and pioneer species such as *Halophila stipulacea, Halodule uninervis, Cymodocea rotundata* and *Thalassia hemprichii*. Monitoring of the pilots is ongoing and will be completed in May 2026. Based on results of rhizome tagging done on the above 4 species in the al Wajh lagoon, the expansion rate of seagrass ranges from 0.17 to 0.95 m yr^{-1}. These results are consistent with rates reported in literature on the same species (Table SG2). Hence, three scenarios, worst-case (0.17 m yr^{-1} expansion), realistic (0.6 m yr-1 expansion), and optimistic (0.95 m yr^{1} expansion) were considered. These were combined with two scenarios of initial survival rate: 30% and 70% initial survival of transplanted units.

Table SG2. | Yearly expansion rates of seagrass species of the al Wajh lagoon from in-house studies or from literature.

Species	Expansion rate (m year^{-1})	Reference
Thalassia hemprichii	0.03 ± 0.17	This study
Halophila stipulacea	0.64	This study
Cymodocea rotundata	0.16 ± 0.95	This study
Thalassia hemprichii	0.88 ± 0.21	Marba and Duarte, 1998[76]
Cymodocea rotundata	0.34 ± 4.11	Marba and Duarte, 1998[76]
Halodule uninervis	0.28 ± 1.38	Marba and Duarte, 1998[76]
Halophila stipulacea	0.07 ± 1.31	Azcārate-García et al., 2020[77]

To calculate net gain from future transplants, we assumed scaling up future transplantation efforts to 2 ha per year (5,000 units each of 0.09 sq. m). If this begins in 2026, this corresponds to a maximum area of 28.2 ha which can be planted by 2039. For this, we have therefore selected the 28.2 ha of habitat with highest seagrass suitability (highest model likelihood). Successful transplanting will increase seagrass cover within these **initial plots** and by outward spread into suitable adjacent areas. Suitable areas (suitability value >0.25) continuous to the 28.2 ha initial planting sites sums to 145.7 km^2 – which we therefore assume to be the maximum area in which planned seagrass transplantation could have benefits.

While seagrass can expand rapidly, there are many factors that limit growth and survival. Therefore, we assume outcomes of transplanting will have same distribution of coverage as found from spot checks, e.g., that only 2.8% of restored seagrass will have >50% coverage (Table SG1). Similarly, as 70% of areas with model suitability >0.25 had no seagrass, we assume probability of transplanted and expansion areas not developing into seagrass meadows to be 70%. At the best-case scenario, the maximum area of seagrass net gain would be of 3.2 km^2 (0.3 km^2 and 2.9 km^2 of high-quality and low-quality habitat, respectively). Considering the large extent of areas with suitability score >0.25, space seems not to be a limiting factor.

We will improve predictions in coming years from better understanding of transplant survival and expansion rates in pilot studies, and from improved models of seagrass habitat suitability that we expect to develop as we improve base seagrass distribution information, and as hydrodynamic models of Al Wajh lagoon become available.

Table SG3. | Net gain of seagrass for different survival and expansion rate scenarios following transplant.

Scenario	30% survival rate	70 % survival rate
0.17 m expansion year^{-1}	0.05%	0.12%
0.6 m expansion year^{-1}	0.58%	1.34%
0.95 m expansion year^{-1}	1.42%	3.3%

Treating expansion rate of 0.6 m yr^{-1} as the most realistic scenario, corresponds to net gain of 0.58 to 1.34% depending on assumptions about initial survival rate of transplants. This is based on assumed scaling up of transplant efforts to 5,000 units of 0.09 sq. m per year. Half or double of the effort would correspond to half or double of the estimated net gain.

We do not include any NCG for seagrass based on use of nurseries, as the potential to harvest source seeds is unknown, and because this approach only has high potential for one species, *Enhalus acoroides*, which is not abundant.

TOTAL PREDICTED CONSERVATION GAIN

Total **predicted seagrass** NCG, based on 0.6 m/yr^{-1} expansion rate is **0.96%** (average of 30% and 70% survival rate).

There are many uncertainties in this estimate, and we do not have available data from large-scale seagrass transplantation efforts elsewhere in the region or other comparable areas to use as a benchmark. As shown in Table SG3, predicted gains are highly dependent on assumed seagrass annual expansion rate – e.g., 5-times higher linear expansion rate corresponds to a 30-fold increased net gain.
However, the above estimates are likely conservative, considering that they are based on assumption that seagrass density in transplanted areas and expansion areas will have similar distribution of cover as mapped seagrass habitat (which includes a lot of low-quality seagrass meadows with very low cover). It seems not unreasonable to assume that cover in enhanced areas will be higher given the considerable scope to select only the most promising locations.

REEF FISHES

Indicators are **Reef fish biomass, large reef fish biomass**, and **encounter rates with rare and vulnerable species.**

ESTIMATED IMPACT OF LARGE-SCALE PROHIBITIONS ON FISHING

Recovery calculated by deriving expected recovery per protection-level from published MPA studies and applying those to the area of coral reef habitat within each level of protection (Tables below), and assuming that AWL FMA (Appendix A) or comparable fishery restrictions are established.

Table RF1. | Predicted gain in reef fish indicators depending on FMA zone.

	AWL FMA Zone			
Indicator	Conservation Priority[1]	Special Management[2]	Sustainable Use[3]	Outside FMA
Fish Biomass	150%	35%	-	-
Large Fish Biomass	200%	65%	-	-
Encounter Rates Rare/Vulnerable Species	300%	25%	-	-
Average Effect	**216.7%**	**41.7%**	-	-

[1]. Meta-analysis of 87 MPAs[39] showed that relative to fished areas, effective MPAs (with 4 or 5 of key features: large, well enforced, no-take, >10 years old, and isolated by sand or deep water) have 170% higher fish biomass; 400% higher large fish biomass; and 545% higher biomass of grouper and snapper (assumed proxy for most vulnerable species). Additionally, RSZ baseline surveys indicate RSZ biomass was around one third to one quarter of biomass on remote and (presumed) very lightly fished reefs in the Red Sea region. Assuming FMA created before 2029, currently planned Conservation Priority zones will meet at least 4 of 5 criteria and likely closer to 5. Therefore, predicted recovery here is a considered a conservative estimate.

[2]. Fishery management within Special Management zones is likely to be in form of prohibitions on netting (as these areas designed to protect vulnerable megafauna), but other forms of fishing will be permitted.

[3]. Potential for recovery of fish populations in sustainable use zones through reduction of total effort and informed-adaptive management not scored here due to uncertainties about effects of planned alternative livelihood strategy and of enhanced management and enforcement, and how these compare to potentially increased effort due to reductions in fishable area within RSZ. Note that reduction of fishable habitat (i.e. proportion of all <30 m habitat unavailable to fishing) = 46.9%. For coral reef habitats, 52% will be unavailable to fishers. However, current expectations are that total fishing effort will decrease from alternative livelihood programs and reductions in numbers of foreign fishers permitted to fish in the area.

Table RF2. | Predicted gain in reef fish indicators per zone based on predicted recovery and zone area.

	AWL FMA Zone			
Increases within zone as proportion of total baseline coral reef fish population	Conservation Priority	Special Management	Sustainable Use	Outside FMA
Average Effect (from above)	216.7%	41.7%	-	-
Area of Coral Reef Habitat (km²)	42.36	0.53	25.42	13.22
% Coral Reef Habitat	52.0	0.6	31.2	16.2
% Positive Impact on Indicators for all RSZ	**112.6**	**0.3**	-	-
TOTAL impact by 2040:				112.9%

TOTAL PREDICTED CONSERVATION GAIN

Total predicted NCG is 113%. Any substantial gain of this scale depends on establishment of large well-enforced no-fishing areas with high compliance. Specific estimates are based on the size of different zones within the proposed Al Wajh Lagoon FMA (Appendix A).

SEA TURTLES

Indicators are **# Hatchlings Produced** by Hawksbill (60%) and Green (40%) turtles.

Assumptions are that hatchlings produced is largely proportional to the number of nesting females but will also increase if hatching success increases – e.g. following improvements to nesting beaches or from nest relocation or shading. We also assume that breeding life span of female turtles is 20 years.

BASELINE NESTING FEMALES & NEST ESTIMATES

Based on 2022-2025 nesting surveys, and standard factors for number of tracks that result in successful nests (50% according to our surveys), and number of clutches laid per nesting turtle per year[78] and assuming that, on average, female turtles nest once every three years.

Green Turtles: 454 nests/year, corresponding with total nesting female population using the area of 231.

Hawksbill Turtles: 213 nests/year, corresponding with total nesting female population using the area of 234.

Table ST1 | Approach to calculating predicted gain for sea turtle interventions.

Green Turtle Actions	Description	Calculation of Gain	2040 Outcome
Breem Sea Cliffs	Avoidable mortalities of 10 turtles in 6 years, equivalent to 0.72 % of female breeding populations that can be saved each year. 19/20 of saved turtles survive to following season (therefore 0.69 %).	(1.0060)^ 15	11% increase in nesting females. Equivalent increase in egg production.
Zoning for boat strike & entrapment mitigation	1 Green turtle mortality per year from boat strike or entanglement. Assume half are female[1]. 19/20 of saved female turtles survive to following season (therefore 0.021 %).	(1.0021)^ 16	3.2% increase in nesting females. Equivalent increase in egg production.
Nest shading	*Potential* for nest shading and assumed 10 % increase in hatching rate[2]. But, not included here, as technological solution not currently available		N/A
Beach Clean Up	Assume improved nesting and hatching outcomes equivalent to 0.5 % more hatchlings[2].		0.5% increase in hatchling production
Green Turtle Total impact by 2040			14.8 %

Hawksbill Turtle Actions	Description	Calculation of Gain	2040 Outcome
Rehabilitation of turtles with floating syndrome and others	6 turtles successfully rehabilitated in 4 years. As-sume 70% mortality avoided. Therefore 0.22% of female breeding populations saved each year. 19/20 of saved turtles survive to following season.	(1.0021)^ 16	3.5% increase in nesting females. Equivalent increase in egg production.
Zoning for boat strike & en-trapment mitigation	2 hawksbill turtles mortalities per year from boat strike or entanglement[1]. Half female.	(1.0041)^ 16	6.4% increase in nesting females. Equivalent increase in egg production.
Nest relocation	5 nests relocated[3]/year (4.7% of nests). Assume 20% increase in hatching rate for Hawksbill nests, which are shallower than Green nests and therefore more vulnerable to overheating[2].		0.5% increase in hatchling production
Beach Clean Up	Assume improved nesting and hatching outcomes equivalent to 0.5% more hatchlings.		0.5% increase in hatchling production
Hawksbill Turtle impact by 2040			10.8 %

Notes: 1. There have been 2 known mortalities of Green turtles in RSZ from boat strike or entanglement between 2021 and 2024 plus three of Hawksbill turtles and one distressed Hawksbill found entangled in net and freed by the team. Not all mortalities will be recorded as dead turtles may sink before washing ashore[79]. We conservatively assume we recorded 50% of mortalities.

2. Increase in hatching rate after relocation or shading are considered conservative approximations, but we were unable to find published data that would allow us to improve those estimates. Notably, their contributions to total estimated recovery are small, and therefore impacts of overestimation would also be marginal.

3.Parts of Waqadi island have low hatchling success, assumed to be because of composition of beach sand there mean-ing nest temperatures more closely track peaks in air temperature and potentially overheat. Relocating some of those nests soon after they are laid to other parts of the island should improve hatching success.

TOTAL PREDICTED CONSERVATION GAIN

Predicted NCG is 12.4% (data above with Hawksbill weighted at 60%, Green at 40%).

Additional benefits may accrue from expanding capacity to rehabilitate a wider range of turtles, from light-management, from increasing production of male hatchlings (although those benefits mostly longer term than 2040), and from increased production of hatchlings entering the breeding population (particularly for Hawksbills that mature earlier), ad potentially from future application of nest shading. However, these are not included in above estimates.

MARINE MAMMALS

Indicators are **relative abundance** from standardized surveys of **priority** (Dugong and Humpback dolphin, 60%) and **other species** (Bottlenose and Spinner, 40%).

For regularly encountered dolphins, we aim to develop indictors of recruitment success that would become 20% of their score.

POTENTIAL POPULATION GROWTH

There is very little published information on medium- long-term changes in dolphin or dugong populations associated with conservation actions of the kind that are feasible in our area. The one study we are aware of, which assessed the impacts over 20 years of establishment of a no gillnetting area in Banks Peninsula Marine Mammal Sanctuary in New Zealand[58]. The benefit for the focal species, Hector's dolphin, was estimated as a 6% increase in mean population growth compared to if the sanctuary had not been established.

Therefore, we use available potential growth parameters to estimate an upper limit on net population growth by 2040, and then adjust those downward to account for factors such as resource scarcity, predation, and residual human-induced pressures.

Specifically, for each species that suitable data is available for, a simplified exponential growth model, $G(2040)=(1+r)^t$, was used with different scenarios of the maximum intrinsic growth rate (r^{max}). In this model G(2040) is population growth by 2040, r = population growth rate, and t = time (in years) from baseline of 2026 (when we assume that conservations interventions will begin.

The two species for which suitable data are available for are Humpback dolphins, for which we used r^{max} of 0.031[80], and Dugong, for which we estimated, three growth scenarios based on assumptions about the species' life history traits (which are currently unknown) [81,82]. For Dugong, the maximum intrinsic growth rate (r^{max}) values were categorized for best -, average-, and worst-case scenarios.

Table MM1. | Dugong Life History Parameters for estimating intrinsic population growth rates.

Dugong Intrinsic Growth Rate Scenario	Age at first reproduction	Mean Calving Interval	r^{max}
Best	6	2.5	0.058
Average	10	2.5	0.035
Worst	10	5	0.003

However, as noted above, the intrinsic maximum growth rate represents the upper theoretical limit of population growth under ideal conditions, where there are no limiting factors. As such, and to reflect a more realistic growth rate, 50% of the maximum intrinsic growth rate was used as a more attainable target to identify the potential percentage increase of the population by 2040.

Table MM2. | Dugong and Humpback dolphin Intrinsic Growth Rate Parameters for modelling maximum potential population gain.

	using r^{max}		using 50% r^{max}	
	r	Pop Growth by 2040	r	Pop Growth by 2040
Humpback dolphin	0.031	53%	0.015	24.0%
Dugong "best-case"	0.058	120%	0.029	49.2%
Dugong "average-case"	0.0305	52%	0.015	23.6%
Dugong "worst-case"	0.003	4%	0.0015	23.8%
Mean Humpback dolphin and Dugong NCG				23.8 %

TOTAL PREDICTED CONSERVATION GAIN

Predicted NCG is 23.8% as derived above.

There is considerable uncertainty in this estimate. Reasons for that include that it is based on intrinsic growth data for only 2 species, and in neither case did growth data come from local studies. Additionally, we are not able to quantify impacts of factors that will limit growth (competition, food limitation, etc.), and instead use a coarse adjustment of 50%.
However, we believe these numbers are not unrealistic. The rates of population growth we use (around 1.5% yr^{-1}) are considerably lower than estimated increase in population growth of 6% for a dolphin species achieved by elimination of netting in a sanctuary in New Zealand[58], and of around 2% for Florida Manatee estimated by a multi-decade population study even though the period included two major die-offs events[83]. Certainly, it is widely believed that Dugong have substantially declined in all parts of the Red Sea where lay gillnets are deployed[55], which includes the RSZ, which suggests high scope for recovery given suitable management and sufficient time. We also do not account for potential population increases from net inward migration of some species, that could occur as the area becomes more suitable for these species following reduction of threats and disturbance.
Currently, we do not attempt to estimate potential positive changes in reproductive success (such as higher calf production or survivorship). Protection of key habitats and recovery of the food base within an FMA may have larger and more rapid effects on reproductive success than on population size, which may therefore also lead to higher NCG than currently predicted.

SHARKS & RAYS

Indicators are **abundance** in standardized surveys of **rare and common species.**

ESTIMATED IMPACT OF ESTABLISHING LARGE NO-FISHING AREAS

To estimate potential gains we compare standardized abundance estimates from baited remote video (BRUV) surveys of lightly-fished remote locations[47] and fished area[s47,48,84] in the Red Sea. BRUVs involve deployment of remote video systems with comparable bait, and nearly all programs including those used here, assess abundance as MaxN h^{-1}: the maximum number observed of each species during a one-hour deployment. The difference in MaxN h^{-1} between fished and relatively unfished benchmark areas provides an indication of the **potential conservation gain** from protection that allows for population recovery to relatively unfished states. An assumption is that steady-state populations will be reached within effective and highly protected zones by 2040.

Specific values used are mean MaxN h^{-1} of 0.53 for unfished reefs in Red Sea, and 0.13 for fished reefs[47,48,84]. This is equivalent to elasmobranch abundance being **307.7%** higher in unfished areas. That scale of difference between fished and unfished reefs is comparable to what has been reported from BRUV studies of effective MPAs elsewhere in the world, including: abundance 276% higher in a study from Belize[85]; 363% higher in a study from Australia[86]; and 97% higher in South Africa[87]. Similarly, a global-scale study using visual survey data from nearly 1,400 sites, found shark abundance to be nearly 300% higher within MPAs than in fished areas[88]. Other large-scale studies have estimated even larger impacts of fishing on reef sharks, including an estimate of 93% depletion of reef shark biomass in fished areas[49], which is equivalent to potential for >1,000% increase in biomass if shark populations fully recover.

Under the proposed Al Wajh Lagoon FMA (Appendix A), 46.9% of shallow habitat (<30 m) would be within highly restricted areas with no permitted fishery harvest. Assuming protections are established of that scale, expected recovery is equivalent to a net increase in elasmobranch abundance of **144.4% across the entire RSZ.**

OTHER KEY ACTIONS

Protection of key habitats, such as shallow nearshore nursery areas is essential to sustain populations and allow for recovery. However, the importance of that is to prevent conservation losses, not to achieve net gain.

It will also be beneficial to improve enforcement of existing prohibition on shark fishing in Saudi Arabia, and there are other potential benefits from gear restrictions in some areas to reduce netting or hook-and-line bycatch, as removing those gears has led to between 25 and 36% higher shark abundance[50]. However, as we have limited information on rates of bycatch, we do not currently incorporate gains from those actions into overall predicted gains.

TOTAL PREDICTED CONSERVATION GAIN

Considering the long lifespans, slow reproduction rates, and differences in life history traits among rays, reef sharks, and wide-ranging sharks, we conservatively assume that, by 2040, we will have realized 50% of the eventual population gain, resulting in a predicted **net conservation gain** by 2040 **of 72.2%.**

Note, we do not believe it is currently feasible to predict recovery at species level, as would be required to generate predictions for common and rare species abundance indicators that will be used to assess conservation progress. Instead, we assume broad patterns of predicted recovery will be consistent across the two indicator groups.

ISLAND BIRDS

Indicators are breeding **population size** (14 species) and **breeding success** (of seven species).

POTENTIAL IMPACTS FROM ERADICATION OF INVASIVE RODENTS

Rats have established populations on 3 RSZ island (Ghawar, Um Rumah 1 and Um Rumah 2). These are large islands with diverse habitats (size from 82.5 to 374.5 ha, considerably larger than 7.3 ha average size of Red Sea Destination (RSD) islands). 7 of the 14 bird species we monitor have been recorded as breeding on those islands, but mostly at relatively low numbers. Collectively they comprise 9.8% of total RSD island area, but host less than 2% of breeding birds. Mice have become established on another 9 islands: Breem, Quman, Ataweel, Sheybarah South and North, Ummahat Alshaykh Islands 1 to 3, and Al Muqaitie Island. These species of rats and mice are unnatural invasive components of these ecosystems. The vector for these invasions is unknown, but on undeveloped islands is most likely to be from fishers that are known to camp on islands during multi-day fishing trips.

Both rats and mice are detrimental to bird populations. Rats have repeatedly been shown to have major impacts on seabirds, primarily through predation on chicks and eggs, but also by competing for food with some species (e.g., by consuming crabs). Consequently, eradication of rats can lead to major seabird recovery - frequently populations increase 10-fold or more post-eradication, although with variability among species, and with full recovery taking 10 or more years.

Published examples include:

- Estimated **18-fold higher** density of breeding sea birds on rat free islands in Chagos archipelago[64].
- **2-10 fold increase** in population of seabirds **10-years after rat eradication** on island(s) in New Caledonia[62].
- Average of **10-fold** higher seabird abundance on islands in Indian Ocean **after rat eradication,** based on comparisons of islands with and without rats, and post recovery of islands where eradication has been successful[61].
- More than **12-fold** increase in number of breeding pairs of seabirds at an Indian Ocean site **17 years after rat eradication** (and increase in number of breeding species)[63].

Overall, therefore, rat eradication has typically led to 10-fold or greater increase in seabird breeding populations. However, there are unique circumstances of RSZ islands that differ from most of these studies. Specifically, islands where rat eradication has been studied generally had dense vegetation including trees, whereas RSZ islands are typically sandy or with patchy scrub vegetation. Consequently, RSZ islands likely have less scope for very large rat populations to develop. Additionally, within RSZ, there are many other islands with potential to support breeding birds, and therefore some of the impact of rats could be to partially relocate seabird breeding to other locations. Therefore, we conservatively assume, rat eradication at RSZ islands would lead to half this previously published effect: a **maximum 5-fold increase in breeding populations,** assuming that populations are not limited by food or nesting habitat availability (discussed below).

Comparison of bird populations and nesting density on islands with rats with other Red Sea Destination (RSD) islands (Table IB1) shows:

- For nearly all species, mean density on rat-infested islands is far below the average density of other islands where the species is present: generally 1/10th or less, other than for Sooty Falcon (around one half of the all-island mean) and Red billed tropicbird (above all-island mean).
- Osprey is the most widely distributed species, but the total number of breeding pairs per island is never more than 6.5 (2-year average), which suggests a natural limitation on their capacity to share even large islands.
- Other than white-cheeked tern, terns are nearly absent from rat-infested islands but are abundant and widely distributed species on RSD islands including nearby islands without rats.

Likely impacts of mice on breeding birds are more difficult to estimate. In a study from New Zealand, where mice competed for food with native terrestrial birds, their eradication led to an around 3-fold increase in breeding populations[89]. However, overlap between mouse and seabird diets is much lower than with terrestrial birds, and potentially very low. It's possible that that mice will at times prey on eggs or small chicks, but we do not have any evidence of this from our area.

Therefore we assume that successful mouse eradication would lead to marginal increases (likely 1% or less) in island bird populations. Given the difficulty and expense of rodent eradication, we do not believe specific eradication efforts are currently justified, but further studies of mouse diet and predation are warranted.

Therefore, predicted gains from rodent eradication limited to three islands where rats are present, with assumption that eradication will increase populations present on those islands 5-fold, but with 3 constraints

- Total number of Osprey pairs on any eradication island cannot exceed maximum previously recorded from any RSZ island (6.5 pairs, Table IB1)
- Predicted density of breeding pairs at any island cannot exceed the maximum density previously recorded at any rat-free island. The one exception to this is Red-billed tropicbird, which has only been recorded on three islands, and for which we therefore have limited information on potential carrying capacity.
- We, conservatively, cap total RSZ population increase for any species to 100% by 2040 – this is only relevant for Sooty falcon and Red billed tropic bird, which have relatively small populations that are limited to a few islands. Therefore, even a 100% increase is a small number of birds, but we prefer to conservative until we better understand the factors that limit their populations.

Table IB1. | Focal Island bird species breeding on Red Sea project islands. Numbers given are averages for last 3 years (2 for Osprey, 1 for Caspian, Saunders's tern) from all islands and separately from the 3 islands where rats are known to be present. Mean density values are for islands where species nest (i.e. not including zero counts from islands where they have never been recorded nesting).

	All RSD Islands					Three Islands with rats			
				Density (Pairs ha^{-1})				Density (Pairs ha^{-1})	
Species	# Island Present	Total Pairs	Max Pairs (island^{-1})	Mean	Max	Total Pairs	Max Pairs (island^{-1})	Mean	Max
Osprey	63	85.0	6.5	0.3	3.6	8.5	3.0	0.02	0.04
Sooty falcon	10	44.0	20	0.04	0.2	8.3	8.3	0.02	0.02
Red-billed tropicbird	9	7.7	3.7	0.004	0.01	3.0	3.0	0.01	0.01
Crab plover	23	1,530.7	360.7	4.4	29.2	152.7	78.7	0.3	0.4
Sooty gull	54	160.0	54.3	0.6	9.8	8.0	8.0	0.02	0.02
White-eyed gull	12	2156.3	461.7	2.3	14.2	48.7	28.7	0.16	0.24
Caspian tern	44	93.0	13	1.7	23.8	1.0	1.0	<0.01	<0.01
Saunders's tern	17	57.0	13	0.1	0.5	-	-	-	-
Bridled tern	35	6,549.2	983.5	14.4	41.1	-	-	-	-
White-cheeked tern	53	11,780.8	905	47.9	444.2	255.7	255.7	1.3	1.3
Lesser crested tern	16	4,971.0	1,538.3	23.9	61.8	-	-	-	-
Great crested tern	1	335.0	335.0	127.3	127.3	-	-	-	-
Brown booby	1	42.7	42.7	0.03	0.03	-	-	-	-
Eurasian spoonbill	1	9.3	9.3	1.2	1.2	-	-	-	-

POTENTIAL IMPACTS FROM PROVISION OF NEST BOXES OR HABITAT IMPROVEMENT

We consider there to be scope to add nest boxes, platforms or other habitats for 4 groups of island birds currently breeding in RSZ: Osprey, Crab Plover, Sooty Falcon, and Terns.
Osprey appear to have natural limits on the number any island can support (Table IB1), and therefore artificial platforms probably have limited utility for enhancing island populations, but still have value for when nests need to be relocated, or if placed along the coast. For Crab plover, there is potential for construction of durable burrows that would provide enduring high quality nesting habitat that could increase carrying capacity. However, these are currently unproven. As such, until pilot studies have been conducted, we don't incorporate those into gain predictions, which are limited to Sooty falcon and Terns.
Artificial nest boxes have been widely used for falcons[65,90], including with some success at Red Sea Destination, at next boxes deployed in 2023 and 2024. These can be very effective. For example, the population of Red-footed falcon around a site in Italy increased from 25 to 82 breeding pairs in 8 years following provision of 117 nest boxes, around 50% of which were used[65]. Very likely, RSZ Sooty falcon populations are constrained by availability of preferred nesting habitat – small caves and crevices on islands. That habitat is highly limited in RSZ, and, where present, such on part of Quman Island, its heavily used. To date, 30 Sooty Falcon nest boxes have been deployed at RSZ islands, but that number could be increased by 100 or more relatively easily. Assuming around 50% of nest boxes would be eventually used, there is scope to double RSZ populations, and potentially more over longer periods.

For terns, moored floating rafts have proven successful elsewhere, supporting densities up to 2.1 breeding pairs m^{-2} with an average of around 1 pair m^{-2} [66–68]. To make significant impacts on RSZ population, the limitation is how many rafts of what size can be realistically deployed. Total tern breeding population in RSZ is around 26,000 breeding pairs yr^{-1}. To increase this by 3% would require around 800 m2 of floating or near-shore platforms deployed in appropriate areas, which we consider a realistic and even conservative target.

IMPORTANCE OF FISHERY MANAGEMENT AND/OR MPA ESTABLISHMENT

Population of seabirds and breeding success can be impacted by fishing through competition with fisheries for prey species and bycatch[69]. Fishing impacts include depletion of predatory fish and dolphin that compete with seabirds, but which sometimes also drive prey species towards the surface where they are more vulnerable to birds. Thus, predicting net effects of fishery management on birds is complex and requires information on behaviors, diets and foraging areas that is not available. Therefore, we do not include any potential seabird gains from improved fishery management or establishment of an MPA – even though there is scope for this to be beneficial, assuming that recovered seabird populations would be close to carrying capacity.

TOTAL PREDICTED CONSERVATION GAIN

Total predicted **island bird NCG** is **19.4%** (Table IB2).

This is based entirely on mean of predicted population increase for 12 of the 14 species (tropicbird and spoonbill, not included due to their tiny populations). The largest portion of predicted gains is from rat eradication on three islands. Effects vary a lot among species, depending on what is already present on those islands, but predictions include largest gains for Sooty falcon, Red Billed tropicbird, Crab plover, and Sooty gull, which includes several of our highest priority species. We don't separately estimate breeding success impacts, but that likely to respond similarly to population (as rat eradication will mostly benefit populations through increased fledgling production).

Table IB2. | Potential for Island Bird enhancement.

	Baseline RSZ	Breeding Population Enhancement		
Species	**Population**	**Rat eradication**	**Nest Boxes**	**% Increase**
Osprey	89.0	11		12 %
Sooty falcon[1]	61.0	15	46	100 %
Red-billed tropicbird	7.7	7.7		100 %
Crab plover	1,530.7	763.3		50 %
Caspian tern	93.0	5.0	2.8	8 %
Saunder's tern	57.0		1.7	3 %
Bridled tern	6,904.2		207.1	3 %
White-cheeked tern	11,787.6	1,278.3	353.6	14 %
Great crested tern	341.0		10.2	3 %
Lesser crested tern	6,711		201.3	3 %
Sooty gull	161.0	40.0		25 %
White-eyed gull	2,156.3	243.3		11 %
Brown booby	43			0 %
Eurasian spoonbill	9			0 %
All Terns	**25,892.8**	**1,283.3**	**776.8**	**8.0 %**
All Gulls	**2,317.3**	**283.3**		**12.2 %**
All Island Birds	**29,950.5**	**2,378.7**	**807.8**	**10.6 %**
Overall NCG (mean % gain excluding tropicbird and spoonbill)				**19.4 %**

Note [1] net overall gain for Sooty falcon population capped at doubling of population. That gain somewhat arbitrarily distributed between at eradication and nest boxes, as both will be used on currently rat-infested islands. However, we assume, current habitat is limiting in absence of artificial nest boxes.

Predicted effects of interventions include a 10.6% increase in the number of breeding birds by 2040 (Table IB2). This implies additional pressure on their prey resources (mostly fishes) and potential for predicted gains to be undermined if prey resources are limited. Strengthened fishery regulation, through MPA or otherwise, should therefore help to sustain predicted gains, and will also likely reduce risk of reintroduction of invasive pests and reduce disturbance during breeding periods.

More generally, effective long-term biosecurity is critical. Rodent eradication requires serious commitment both to eradicate them, and to prevent their later reintroduction. Biosecurity management must therefore account not only for RSZ boats, but all vessels and people with potential to visit the islands.

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