Identifying coastal and marine priority areas for conservation in the United Arab Emirates

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ORIGINAL PAPER

Identifying coastal and marine priority areas for conservation in the United Arab Emirates

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Abstract

The waters of the United Arab Emirates (UAE) host a diversity of marine and coastal habitats that are under increasing pressure from multiple anthropogenic activities related to rapid economic growth. In response, Marine Protected Areas (MPAs) currently cover 12% of the UAE's coastal and marine zones. The UAE National Biodiversity Strategy and Action Plan aims to increase the extent of protection to 14% by 2021, a target that exceeds current global commitments. We applied systematic conservation planning to (1) assess whether conservation features (i.e. species and habitats of conservation concern) are adequately represented in the current system of MPAs, and (2) identify complementary coastal and marine priority areas for conservation and management. Eight planning scenarios were produced based on different conservation targets, the inclusion (or not) of existing MPAs in the generated solutions, and the consideration (or not) of dredging (an activity linked with coastal development in the UAE). A gap analysis demonstrated that to achieve the targets set by experts for all conservation features, additional areas would need to be integrated in conservation plans and policies. Key coastal and marine priority areas were consistently selected for conservation across all planning scenarios. The findings of this work provide a basis for the identification of conservation priorities that can be embedded in the current network of MPAs by extending their boundaries, in post-2020 conservation strategies including plans for creating new MPAs, and in broader spatial planning initiatives.

Keywords Systematic conservation planning · Marine protected areas · Dredging · Expert knowledge · Gap analysis · Conservation priorities

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Introduction

Worldwide, nations are increasing their efforts to protect their coastal and marine environment to meet global conservation targets agreed under the Convention on Biological Diversity (CBD) (Lubchenco and Grorud-Colvert 2015). In the Arabian Gulf, the designation and implementation of Marine Protected Areas (MPAs) is a key spatial management tool being used for the protection of vulnerable coastal and marine ecosystems (Naser 2014). In the United Arab Emirates (UAE), 15 MPAs have been established by the authorities (10 in the Arabian Gulf and 5 in the Gulf of Oman), covering 12% of the UAE's Exclusive Economic Zone (MPAtlas 2018). By 2021, the UAE National Biodiversity Strategy and Action Plan (NBSAP) aims to increase protection of marine areas to 14%, exceeding the current 10% commitment agreed under the CBD Aichi Target 11 and the United Nations Sustainable Development Goal 14 for 2021. These global targets are expected to be revised as part of the Post-2020 Global Framework for Biodiversity under the CBD.

Although setting quantitative goals is very important for biodiversity conservation, further considerations are required to ensure that spatial protection and management measures are effective. The CBD Aichi Target 11 specifies that: "10% of areas of particular importance for biodiversity and ecosystem services need to be conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures". Focusing only on the percentage coverage of protection and sustainable management may result in selection of protected areas of limited conservation value that are poorly connected (Visconti et al. 2019). Therefore, rigorous methods that consider the adequacy and representation of species and habitats are necessary to prioritize areas for conservation and to designate well-connected networks of MPAs. The recent Global Assessment on Biodiversity and Ecosystem Services (Diaz et al. 2019) showed that while moderate progress has been made towards ecological representativeness for areas of importance for biodiversity, the connectivity of MPAs has not yet been assessed (Gannon et al. 2017).

Systematic conservation planning (SCP) provides a clear, comprehensive framework for guiding the location, configuration, and management of biodiversity conservation areas (Moilanen et al. 2009). The core principles of SCP (connectivity, adequacy, representativeness and efficiency) have been increasingly implemented around the globe to support the design of MPA networks (e.g. Fernandes et al. 2005; Giakoumi et al. 2012; Jumin et al. 2018). A connected and representative network of MPAs provides species with multiple refuges in the network system and ensures persistence of species and habitats along with the processes that support ecosystem functioning (Roff 2014; PISCO and UNS 2016). An efficient network of MPAs is one that is connected, adequately sized and representative, while minimizing costs to other human activities (Van Lavarien and Klaus 2013; Roff 2014; PISCO and UNS 2016). Therefore, SCP and relevant spatial prioritization software can assist conservation practitioners and decision-makers to achieve national and international conservation targets by efficiently identifying areas of high conservation value (Pressey and Bottrill 2009).

The marine realm of the United Arab Emirates (UAE) encompasses a variety of coastal and marine ecosystems with rich biodiversity that provide multiple services to humans (Tourenq and Launay 2008; AGEDI 2013). Several habitats, including seagrass beds, coral reefs, mangroves, algal mats and mudflats contribute significantly to natural carbon storage, the provision of seafood, recreation, as well as the resilience to climate change impacts (Duarte et al. 2020; Vaughan et al. 2019). Increased resilience against climate change (e.g. increased sea surface temperature) is especially important, as its impacts in this region are expected to be particularly severe (Wabnitz et al. 2018; Riegl et al. 2018). Moreover, UAE's waters host iconic marine reptiles and mammals such as the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricata*) and the dugong (*Dugong dugon*). Noticeably, the Arabian Gulf waters host the second largest population of dugongs in the world (Preen 2004; Javado and Javelle 2013), with approximately 40% of the Arabian Gulf population occurring in the UAE (EAD 2017). Despite the importance of these coastal ecosystems and species, the high concentration of human activities along the coast of the UAE has put growing pressure on the health of these important natural assets (Burt 2014; Burt and Bartholomew 2019). To secure more sustainable development for the UAE, important coastal and marine species and their habitats require enhanced protection and management (Tourenq and Launay 2008; AGEDI 2013; Jabado et al. 2015; Javed et al. 2019).

Considering current conservation needs and upcoming national and international commitments for further protection of marine biodiversity, we first assessed whether species and habitats of conservation concern are adequately represented in the current system of MPAs and, then by implementing SCP, we identified complementary coastal and marine priority areas for conservation and sustainable management. Ultimately, we aimed to support biodiversity conservation decision-making in the UAE by highlighting areas of high conservation value that should be integrated into a well-connected and ecologically representative network of protected and managed areas to achieve effectively national and global conservation targets.

Methods

Study area

The UAE's waters extend in the Arabian Gulf and the Gulf of Oman. This study focused only on the Arabian Gulf waters and adjacent coastal zone extending 5 km inland to include intertidal habitats (Fig. 1). UAE waters in the Gulf of Oman were excluded due to insufficient data on the distribution of habitats and species in this region. Our study area covered 57,401 km^2, which was divided into 14,603 hexagonal planning units (PUs) of 4 km^2 each. Currently, ten MPAs are present in the study area, which together cover 12% of its extent (Table 1).

Identification of conservation features and target setting

Conservation features (i.e. species and habitats of conservation interest) were identified based on their ecological and socio-economic importance (for ecosystem functioning and service provision) and data availability (Mateos-Molina et al. unpublished data). Subsequently, an expert knowledge elicitation process was followed to set conservation targets for the features. Local experts included scientists and scientific officers from academia, environmental authorities, and non-governmental organizations working on coastal and marine biodiversity. Experts were selected based on their knowledge in the conservation features, and their expertise in current national and international policy agreements of the UAE. Experts were asked to individually assign a target to each feature based on the ecological and socio-economic value of the species or habitat, its known conservation

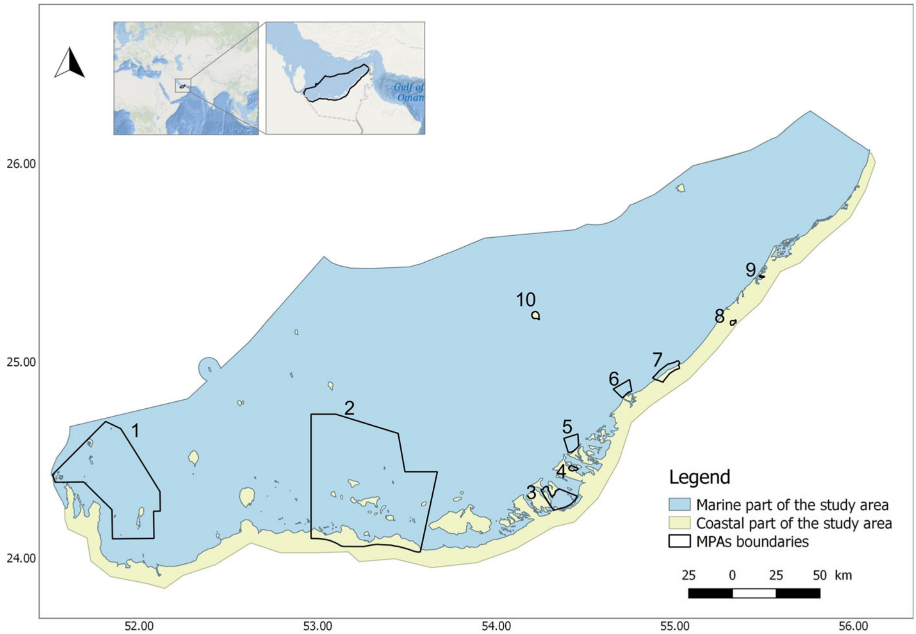


Fig. 1 Study area including the marine waters and coasts of the UAE in the Arabian Gulf. Numbers represent marine protected areas (MPAs) as following: 1: Al Yassat MPA, 2: Marawah MPA, 3: Bul Syayeef MPA, 4: Mangrove National Park, 5: Al Saadiyat Marine National Park, 6: Ras Ghanada MPA, 7: Jebel Ali MPA, 8: Ras Al Khor Wildlife Sanctuary, 9: Al Zorah MPA, 10: Sir Bu Nair MPA

Table 1 Marine protected areas characteristics in the study area. Data was provided by Emirates Nature-WWF

Emirate	Name (*)	Type	Area (Km^2)	Date of declaration
Abu Dhabi	Marawah	MPA and Marine Biosphere Reserve	4,255	2001
	Al Yassat	MPA	2,046	2005
	Al Saadiyat	Marine National Park	59.25	2017
	Ras Ghanada	MPA	54.6	2017
	Bul Syayeef	MPA and Ramsar site	145.2	2017
	Mangrove	National Park	9.9	2017
Dubai	Ras Al Khor	Marine Wildlife Sanctuary and Ramsar site	6.2	1998
	Jebel Ali	Marine sanctuary and Ramsar site	28.76	1998
Sharjah	Sir Bu Nair	MPA and Ramsar site	49.3	2000
Ajman	Al Zorah	MPA and Ramsar site	1.4	2004

status within the local context, and international recommendations. For the purpose of this study, targets were expressed as a percentage of the feature's known distribution range. Subsequently, the same experts attended a workshop during which graphical representations of their assessments were shared. Discussions followed, and experts reached an agreement on the percentage of the distribution range of each conservation feature that is required to ensure the viability and persistence of the specific feature in the study area.

Two sets of targets were agreed: the first included optimum (or high) targets (Table 2), whereas the second included lower targets (calculated as the initial high targets reduced by 20%) to explore a minimum acceptable threshold for each conservation feature. However,

Table 2 Optimum conservation features' targets (%) and total coverage in the study area (km^2), conservation features for which non-negotiable targets were set are designated with an asterisk (*)

	Conservation feature	Total coverage (km^2)	Conservation target (%)
Reptile, mammals and marine bird species	Sooty Falcon breeding areas	5.99	100
	Hawksbill turtle feeding areas	4351.97	70
	Greater flamingo breeding/ roosting areas	79.5	100
	Socotra cormorants roosting areas	3490.93	60
	Hawksbill turtle nesting areas*	4.21	100
	Socotra cormorants breeding areas	26.25	90
	Crab plover breeding areas	15.88	100
	Lesser crested tern breeding areas	18.65	100
	Dugong feeding areas*	332	95
Subtidal habitats	Hard bottom & Pearl Oysters beds	66.32	80
	Hard bottom & Macroalgae	510.86	50
	Unconsolidated bottom	9273.43	30
	Hard bottom & Coral*	29.81	70
	Seagrass	1430.68	80
	Hard bottom	492.99	30
	Reef + Corals*	132.95	95
	Reef	281.99	80
	Reef + Macroalgae	265.46	80
Intertidal habitats	Coastal Sabkha	8650.98	60
	Mangroves	176.02	85
	Rocky shore*	3.89	80
	Coastal lagoon	17.79	90
	Saltmarshes	57.02	70
	Algal mat	69.05	80
	Beach	16.56	60
	Mudflats	315.23	70

for five features the targets were not reduced (rocky shores, dugong feeding areas, hawksbill turtle nesting grounds, hard bottom with corals, and reef with corals). Experts argued that targets for these conservation features were non-negotiable due to the features' uniqueness, vulnerability to human pressures (including climate change), and currently narrow distribution range. To effectively protect species that use multiple habitats during their daily or life cycles, targets were set for nesting and feeding grounds for turtles and birds. Links between species and the different habitat types were also considered (e.g. dugongs and seagrass distribution). This approach increases the probability of persistence of species that use areas that may not be spatially connected but connected through the movement of species for ecological needs (such as reproduction, feeding, or roosting).

Considering (1) the targets for each conservation feature set by experts and (2) the extent of each feature that is covered under the current configuration of the existent MPAs, we conducted a gap analysis to estimate the gap between current protection and desired protection.

Collection of data on socio-economic variables and pressures

Dredging is associated with multiple activities in the Arabian Gulf, such as land reclamation, creation of transport channels and for urban development (Alzaylaie and Abdelaziz 2016). It is one of the most widespread and impactful pressures to marine species and ecosystems in the region (Sale et al. 2011; Burt et al. 2013; Burt 2014). Updated information on areas where dredging occurs was obtained from the habitat map provided by Emirates Nature-WWF and refers to activities during the year 2017 (Emirates Nature-WWF 2019). Given the possible spread of impacts from dredging on surrounding vulnerable marine species and habitats, e.g. corals (Sheppard et al. 2010; Erftemeijer et al. 2012), a buffer zone of 1 km was created around the dredging areas. The percentage of the dredging spatial coverage per PU was calculated after transferring the dredging data into our planning grid (Fig. 2).

Spatial conservation prioritization

To select additional priority conservation areas, Marxan software (Ball et al. 2009) was applied. Worldwide, Marxan is the most widely used conservation planning tool (Sinclair et al. 2018). It uses a simulated annealing algorithm to find a range of near-optimal systems of priority areas that meet the conservation targets while minimizing socio-economic costs.

We produced two sets of planning scenarios: one considering only ecological data (group a) and one considering both ecological and socio-economic data (i.e. dredging; group b). Overall, eight different planning scenarios (Fig. 3) were produced based on:

(1) The way cost was estimated,
(2) Different sets of conservation targets (high and low), and
(3) The forced selection of PUs included in MPAs (or not),

As the inclusion of cost in conservation planning solutions is a very important factor that influences the identification of priority areas (Mazor et al. 2014), we applied different ways of estimating cost. In the first group of planning scenarios (group a, Fig. 3), the cost was equal to the area included in the planning solution. In the second (group b, Fig. 3), a dredging cost was calculated as the sum of the area cost plus a Dredging Penalty (DP): if the Dredging Percentage in the Planning Unit (DPU) is equal to 0%, DP = 0; if

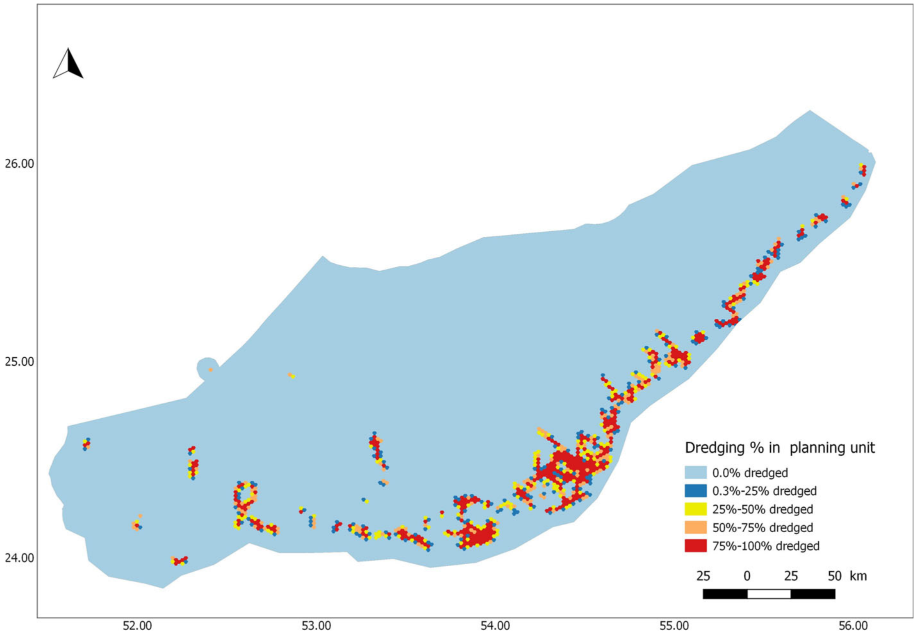


Fig. 2 Percentage of dredging area in planning units (PUs). The warm colors represent higher dredging percentage in the PUs

$0.3\% < DPU < 25\%$, DP = 1000; if $25\% < DPU < 50\%$, DP = 2000; if $50\% < DPU < 75\%$, DP = 3000; if $75\% < DPU < 100\%$, DP = 4000. These thresholds were based on expert judgement and local knowledge. Moreover, to give more flexibility to Marxan in finding the most efficient planning solutions, we decided to test two different sets of conservation targets (see "Identification of conservation features and target setting"). For the same reason, we decided not to force the selection of current MPAs in the planning solutions for some scenarios, so that Marxan could identify priority areas that represent conservation features adequately and most efficiently not being compromised by the existing MPA network.

Marxan was run 100 times, from which a best solution was produced for each scenario that met all targets with the lowest cost and boundary penalties. Spatially compact solutions are an important consideration for the design of networks of protected areas (Roberts et al. 2003). To obtain the desired level of spatial compactness for each scenario, the Boundary Length Modifier (BLM) was calibrated to generate a reasonable trade-off between boundary length and cost (Stewart and Possingham 2005), using Zonae Cogito software (Watts et al. 2009). BLM values between 5 and 8 were used. The spatial overlap between best solutions produced for each scenario was measured using Cohen's Kappa test. Pairwise comparisons were applied to the best solutions using R software (R Core Team, 2019) to measure the similarity after removing overlap due to chance (Landis and Coch 1977).

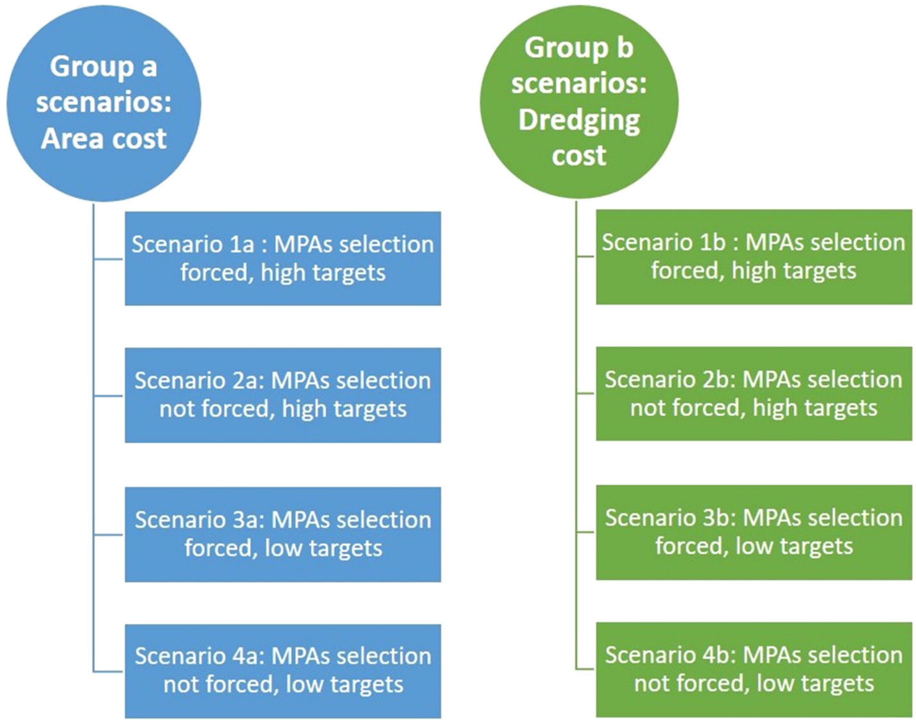


Fig. 3 Chart summarizing the eight scenarios and their characteristics by groups (a and b)

Results

Current achievement of targets

Overall, existing MPAs encompassed most conservation features. However, the assessment of the gap between current protection and desired protection (based on the conservation targets set by experts) demonstrated that most conservation features are not adequately represented in the current system of MPAs (Fig. 4a–c). Some features were better represented in MPAs than others. For example, 71% of dugong feeding areas were included in MPAs, and thus only 24% more area needs to be protected or managed to achieve the target set by experts. On the other hand, hawksbill turtle nesting and feeding areas were poorly represented, as the gaps were 75% and 60%, respectively. The gaps for marine birds breeding and roosting areas ranged between 41% for Socotra cormorants roosting areas to 100% for sooty falcon breeding areas. Concerning subtidal habitats (Fig. 4b), the targets set by the experts were fully met only for hard bottom habitats. For the other conservation features, the gap ranged between 3% (for the unconsolidated bottom) and 80% (for hard bottom and pearl oyster beds). For intertidal habitats (Fig. 4c), features for which large differences between current protection and desired protection were identified (i.e. gap larger than 50%) include: coastal lagoons (78%), mangroves (76%), rocky shores (70%), and coastal sabkhas (58%).

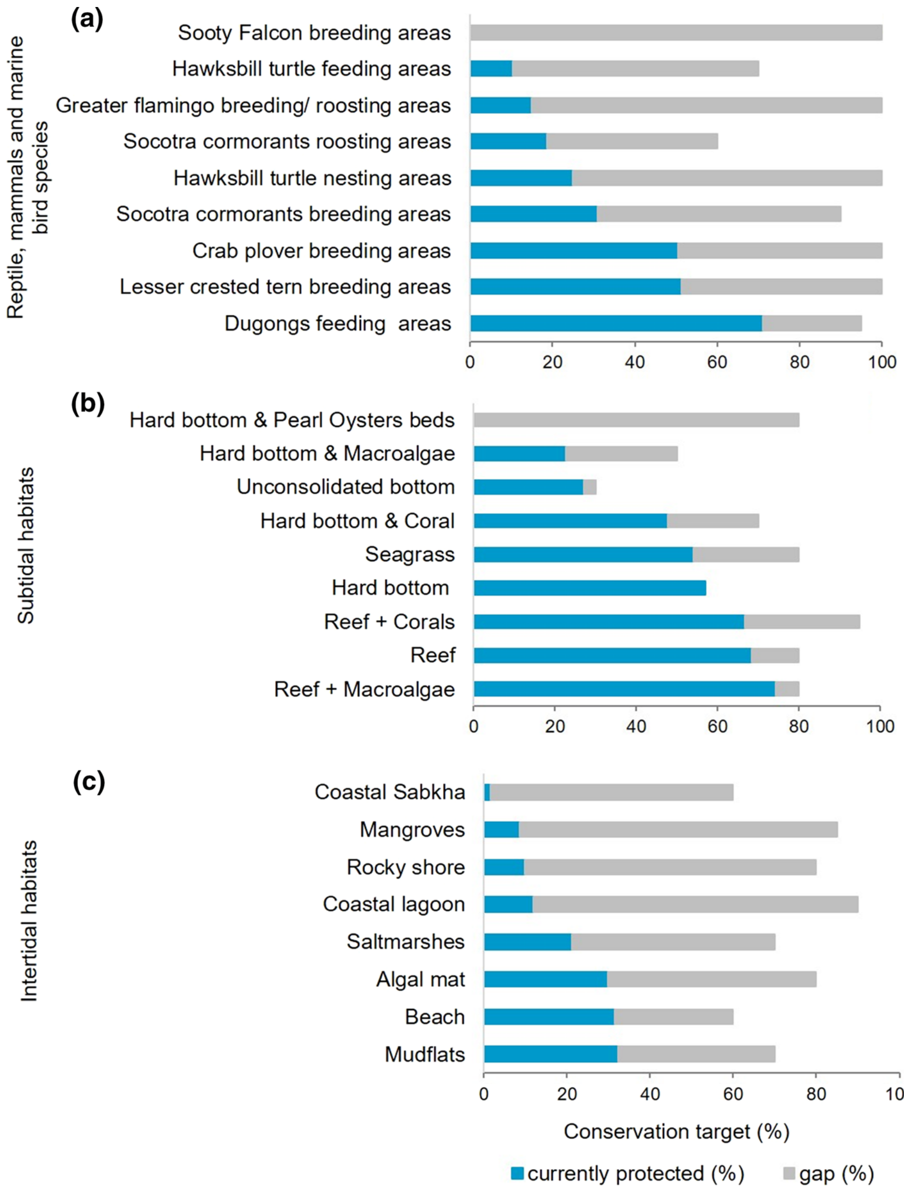


Fig. 4 Gap analysis on conservation targets. The bars represent the conservation targets for each feature set by the experts. The blue part of the bar represents the percentage that is already protected/ managed in existing MPAs whereas the grey part represents the remaining percentage to achieve the target set

Selection of marine and coastal priority areas for conservation

When the selection of MPAs was forced into Marxan solutions and high conservation targets were set, our best planning solutions accounted for 23% of the study area (13,076 km^2) in scenario 1a, where cost was estimated as area, and 22% (12,808 km^2) in scenario

Fig. 6 Best solutions of the eight scenarios. The green color represents selected area inside MPAs, the purple color represents the area inside MPAs that are not selected, while the pink color represents the area selected outside MPAs (1a: MPAs selection forced, high targets, area cost/1b: MPAs selection forced, high targets, dredging cost/2a: MPAs selection not forced, high targets, area cost/2b: MPAs selection not forced, high targets, dredging cost/3a: MPAs selection forced, low targets, area cost/ 3b: MPAs selection forced, low targets, dredging cost/4a: MPAs selection not forced, low targets, area cost/4b: MPAs selection not forced, low targets, dredging cost). Numbers represent MPAs as following: 1: Al Yassat MPA, 2: Marawah MPA, 3: Bul Sayayeef MPA, 4: Mangrove National Park, 5: Al Saadiyat Marine National Park, 6: Ras Ghanada MPA, 7: Jebel Ali MPA, 8: Ras Al Khor Wildlife Sanctuary, 9: Al Zorah MPA, 10: Sir Bu Na'air MPA

1b, where dredging cost was applied (Fig. 5). When low targets were set, less area was required for the best solutions, corresponding to 19% (11,316 km^2) of the study area in both scenarios 3a (area as cost) and 3b (dredging cost). In these four scenarios (i.e. 1a, 1b, 3a, 3b), areas closer to MPAs were selected to achieve the conservation targets (e.g. next to Marawah and Al Yassat MPAs; Fig. 6). By extending the borders of existing MPAs, the achievement of conservation targets improved for several conservation features such as hawksbill turtle nesting areas, mangroves, rocky shores, hard bottoms, and pearl oyster beds. Additional coastal and marine priority areas in the northern emirates, far from current MPAs, were identified to ensure inclusion of unique conservation features such as Socotra cormorants breeding areas, coastal lagoons, and mangroves (Fig. 6).

When the selection of MPAs was not forced, best solutions accounted for smaller proportion of the study area. When high targets were set, the best solutions covered 17% of the study area (9864 km^2) in both scenarios 2a (area cost) and 2b (dredging cost). When low targets were set, the best solutions corresponded to 12% of the study area (6888 km^2) in scenario 4a (area cost) and 13% (7462 km^2) in scenario 4b (dredging cost).

The application of Cohen's Kappa test for pairwise comparisons between scenarios' best solutions revealed that the solutions' agreement (i.e. spatial overlap) ranged from "moderate" to "almost perfect agreement" (Supplementary Table S1). There was "almost perfect agreement" (Kappa test values between 0.8 and 1, $p < 0.001$) between the solutions of all scenarios in which the selection of MPAs was forced into Marxan solutions,

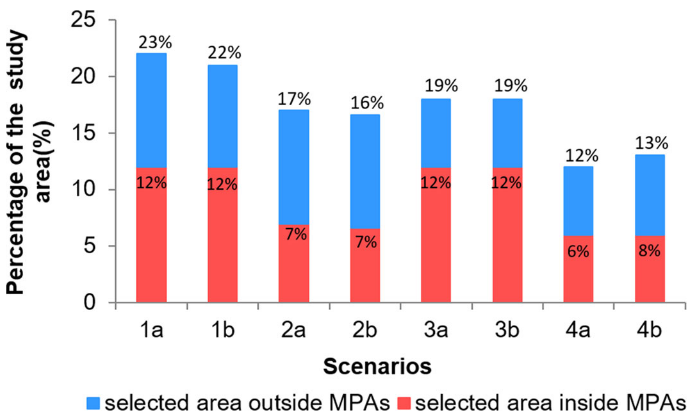
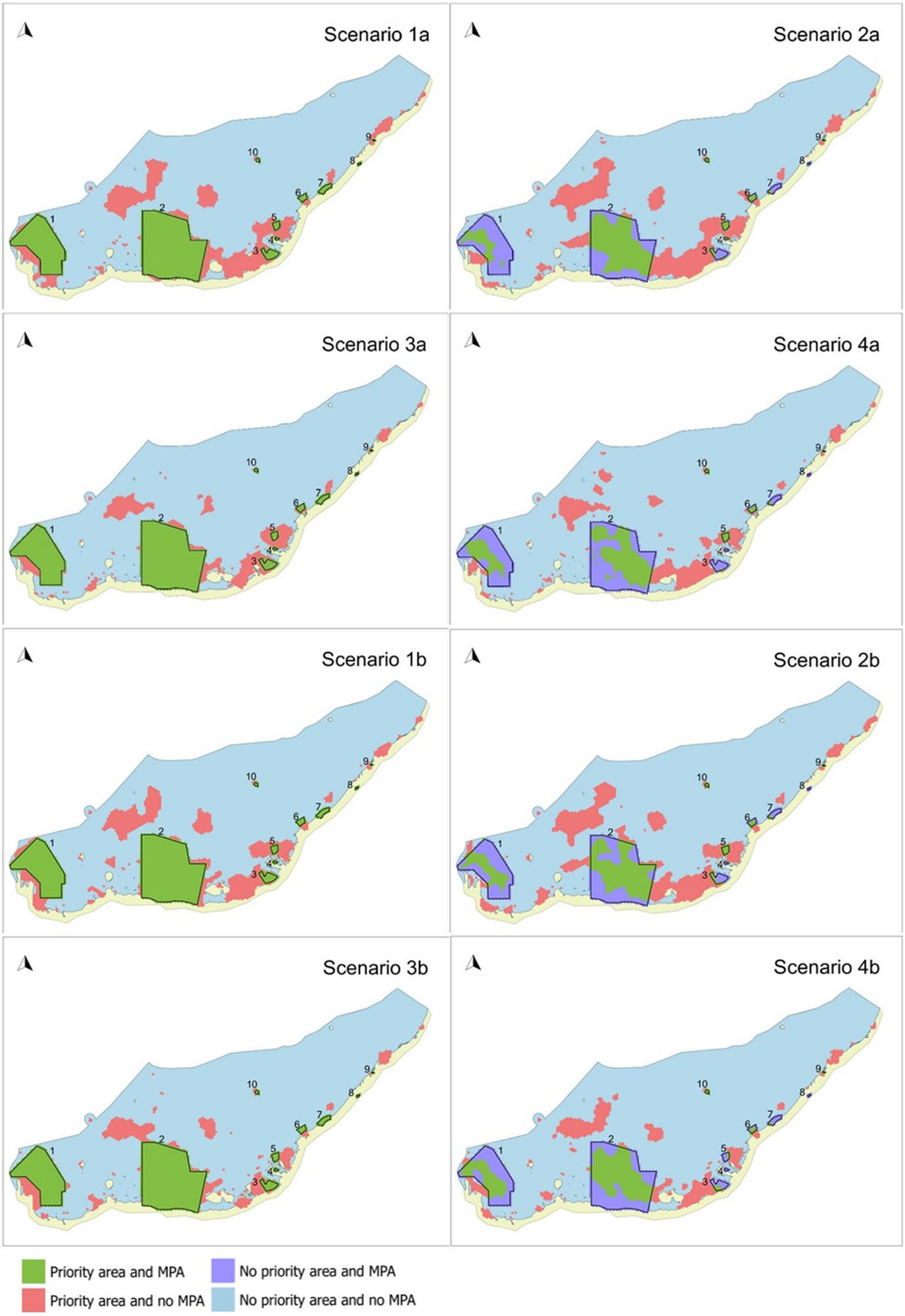


Fig. 5 Percentage of the study area that was selected in each best solution of the eight scenarios. The bars represent the overall percentage of the study area that was selected in the best solution of each scenario. The red part of the bar represents the selected area that is already protected/managed in existing MPAs whereas the blue part represents the selected area outside the protected/managed areas


Scenario 1a
Scenario 2a
Scenario 3a
Scenario 4a
Scenario 1b
Scenario 2b
Scenario 3b
Scenario 4b
1
2
3
4
5
6
7
8
9
10
Priority area and MPA
Priority area and no MPA
No priority area and MPA
No priority area and no MPA

regardless of the use of different targets (high or low) and different types of costs (area or dredging). When the selection of MPAs was not forced, there was "substantial agreement" (Kappa test values between 0.6 and 0.8, $p < 0.001$) between scenarios with the same targets even if they had different costs. On the other hand, the way cost was estimated appeared to be a less influential factor for determining the similarity between scenarios. Scenarios with the same cost but with different targets and treatment of MPAs (forced selection or not) presented only "moderate agreement" (Kappa test values between 0.4 and 0.6, $p < 0.001$).

Discussion

The marine and coastal zones of the UAE contain a mosaic of critical habitats such as mangrove forests, seagrass beds and coral reefs, and these support a variety of vulnerable charismatic species such as dugongs, green turtles and hawksbill turtles, as well as numerous commercially important species (Vaughan et al. 2019). The gap analysis we performed showed that current MPAs provide only partial protection for most species and habitats. By implementing SCP, we identified coastal and marine areas of high conservation value that complement MPAs and allow the achievement of the targets, set by the local experts, for all conservation features.

Multiple planning scenarios were produced and compared. The solutions provided by the ecological scenarios (group a) were more efficient (i.e. required less area for achieving same targets) when the selection of MPAs was not forced in the planning solutions. This was because current MPAs include areas that are not critical for achieving the targets set for the conservation features considered in this study. Even though some non-critical areas for the conservation features are included in MPAs, the current system of MPAs provides a basis to create an ecologically meaningful and efficient network of MPAs in the UAE. When the selection of MPAs was forced in the planning solutions, additional areas were selected in adjacent waters to complement existing MPAs to achieve the conservation targets. This suggests that a potential expansion of the MPAs delineation can be considered as a feasible conservation option. It is worth noting that in all scenarios (groups a and b), new areas were selected in the northern emirates to include unique features such as mangroves, seabirds and their breeding areas that were underrepresented in the existing MPA framework.

The percentage of the study area recommended to be managed for achieving the conservation targets ranged between 12 and 23% depending on the scenario. Since 12% of the study area is already protected, an additional 11%, at maximum, is recommended to be included for further protection and management. Conservation approaches and effective management options for these areas could be achieved by using strategies that might contribute to the protection of the fragile coastal and marine ecosystems, including MPA designation, environmental regulations, ecological restoration, and ecosystem-based management strategies (Van Lavieren and Klaus 2013; Naser 2014; Burt et al 2017).

The comparison of planning solutions showed that the selection of MPAs (forced or not) and the conservation targets (high or low targets) were the factors that determined the spatial overlap between planning solutions. The observed high spatial overlap among planning solutions was mainly due to the fact that the conservation targets set by the local experts were high for most conservation features (above 50% of the feature's distribution), because most critical conservation features currently have a restricted distribution compared to their historical distribution. Furthermore, the rates of degradation are high, particularly considering human pressures combined with climate related stressors that are expected to be further exacerbated in the future (Alzaylaie and Abdelaziz 2016). By setting high targets, the generated planning solutions are expected to secure the persistence of the selected conservation features. Interestingly, cost (defined as area or dredging cost) was less influential in determining the spatial overlap among the planning solutions. This finding contradicts evidence from other studies conducted in other marine ecoregions (e.g. Giakoumi et al. 2013; Mazor et al. 2014). This might be the case because the cost estimation was based solely on dredging data and did not include other important human activities in the region, such as fishing and oil exploitation, due to lack of data.

The application of SCP presented herein has certain limitations, mainly due to limited availability and quality of data for the study area. More specifically, information on the distribution of key marine predators such as dolphins and sharks were not included because the data were sparse. Data on the distribution and/or spawning grounds of commercial fishes were also limited, and thus not included in the current study. Moreover, data on the movement of green turtles (obtained e.g. by telemetry) were insufficient, as the monitoring program was still running at the time of this study and therefore did not allow us to account for functional connectivity in a more comprehensive manner. Importantly, this study excluded the marine realm of the UAE's eastern shores on the Gulf of Oman due to limited data availability. Habitat mapping and species monitoring efforts should be extended into the Gulf of Oman to allow the identification of conservation and management priorities throughout the entire UAE coastal marine system. While mapping has been performed for some ecosystems on the Gulf of Oman coast (e.g. coral reefs, Grizzle et al. 2016), to date a comprehensive multi-habitat mapping exercise has yet to be performed.

Besides the lack of ecological data for certain species and regions, information about the distribution of main uses of marine systems was unavailable. Such data would have allowed a more realistic estimation of the cost (i.e. forgone opportunities for other uses) of the various planning solutions. Yet, in human-dominated regions, the use of cost from several uses in SCP may hinder the achievement of conservation targets for all features, especially when the targets are high (Markantonatou et al. unpublished data). The reason for this is the high overlap between critical areas for species and habitats and areas of intense human use. In this study, we prioritized the achievement of the targets set for all conservation features in order to identify areas of high conservation value regardless of the distribution of socio-economic activities. As in Geselbracht et al. (2009), we did not want to de-emphasize the importance of biodiversity sites that were also important for socio-economic uses. The identification of high conservation value areas would then allow us to stimulate discussions with decision-makers and stakeholders on what management measures could be implemented to effectively conserve marine biodiversity and maintain ecosystem services.

For the future, an SCP approach that considers both ecological and socio-economic data could be valuable to assess the degree of environmental impact mitigation on these areas as well as increase conservation measures. This would require categorizing the human activities that put pressure on biodiversity as stoppable (or manageable) and unstoppable (or unmanageable) (Giakoumi et al. 2015). Manageable threats that can be addressed either by protection of priority areas, or spatial management of activities (such as fishing restrictions in certain areas or periods), could be regulated a posteriori whereas unmanageable challenges at a local scale (such as marine areas particularly vulnerable to climate change) should be avoided a priori. At the same time, SCP could be an efficient way to incorporate climate refugia (i.e. areas that facilitate the persistence of species during long-term climate change) into the network of MPAs in the UAE (Groves et al. 2012), where climate change is likely to further exacerbate pressures caused by rapid changes of land and marine uses. In the light of new evidence (both ecological and socio-economic), conservation/management priorities and actions could be re-considered, re-assessed, and re-located (if needed) to adapt to the new conditions. Such management approaches have been applied elsewhere in this region, where ecosystem-based approaches were used in a similar highly developed and rapidly changing coastal and marine environment to better inform the management of future coastal development (Burt et al. 2017).

This study is based on the best, currently available scientific information and offers robust recommendations for spatial conservation and management prioritization. The results of this work can inform future policies at a national and emirate level related to spatial use planning and management, biodiversity action plans, new protected or managed areas delineation, as well as other area-based management tools that can support the sustainable management of these marine ecosystems. Our findings provide a foundation that can support further engagement with competent environmental authorities to refine spatial configuration of the selected priority areas by considering additional information on human uses. The process of engaging with key stakeholders and competent authorities has already begun, in an effort to integrate the results from this study within national and emirate level conservation action plans, protected areas planning framework as well as wider spatial planning policies and initiatives. The outputs of this study are also expected to provide further support for future national conservation strategies in line with the revised global targets and commitments under the Post-2020 Biodiversity Framework and provide an effective case study on how spatial prioritization can be implemented at a national level contributing to global processes.

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