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Abu Dhabi Global Environmental Data Initiative

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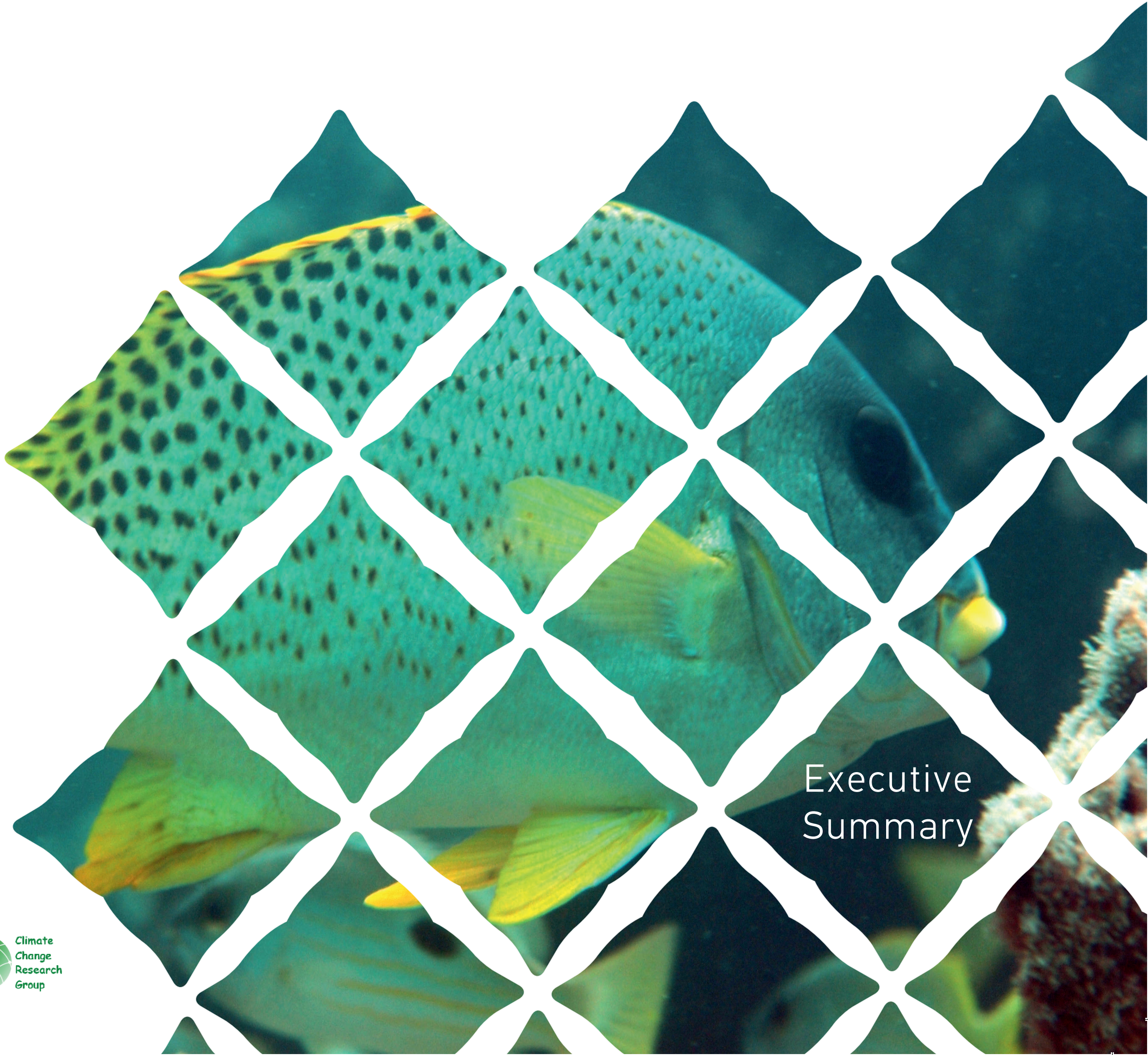
Environment Agency - ABU DHABI

LOCAL, NATIONAL, REGIONAL CLIMATE CHANGE PROGRAMME

MARINE BIODIVERSITY AND CLIMATE CHANGE

- Atmospheric Modelling
- Arabian Gulf Modelling
- Marine Biodiversity & Climate Change
- Marine Ecosystems
- Transboundary Groundwater
- Water Resource Management
- Al Ain Water Resources
- Coastal Vulnerability Index
- Desalinated Water Supply
- Food Security
- Public Health Benefits of GHG Mitigation
- Sea Level Rise



Executive Summary

SEA AROUND US

UBC

Climate Change Research Group

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Published by: Abu Dhabi Global Environmental Data Initiative (AGEDI), 2016.

Suggested Citation: AGEDI. 2016.
Executive Summary Regional Marine Biodiversity and Climate Change.
LNRCCP. CCRG/UBC/CORU/SAU.

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Local, National and Regional Climate Change Programme 2013-2016

Socioeconomic Systems	Regional Climate Change	Environment	Coastal Zones	Water Resources
Public Health Benefits of GHG Mitigation (L)	Atmospheric Modelling (R)	Terrestrial Ecosystems (R)	Coastal Vulnerability Index (N)	Al Ain Water Resources (L)
Food Security (N)	Arabian Gulf Modelling (R)	Marine Ecosystems (R)	Sea Level Rise (R)	Water Resource Management (N)
Desalinated Water Supply (R)				Transboundary Groundwater (R)

L=Local N=National R=Regional

5 Thematic Areas 3 Spatial Regions 12 Sub-projects

12 Sub-projects
Assess the Impacts, Vulnerability & Adaptation to Climate Change in the Arabian Peninsula

Acknowledgments

Many individuals provided invaluable support, guidance, and input to the Marine Biodiversity and Climate Change project. The authors would like to express their sincere and heartfelt gratitude to them for taking the time to review our reports, provide comments, feedback, and data as well as for the opportunity to present multiple deliverables within the course of the project. These individuals include but are not limited to the below list:

Mr. Abdul Rahman Abdulla, Dubai Municipality (DM)

Dr. Ebrahim Abulkader, King Fahd University of Petroleum and Minerals

Mr. Edwin Grandcourt, Environment Agency - Abu Dhabi (EAD)

Dr. Farhad Kaymaram, Iranian Fisheries Research Organization

Dr. Frederic Launay, Environment Agency - Abu Dhabi (EAD)

Dr. Friedhelm Krupp, Qatar Museum of Nature & Science

Dr. Himansu Das, Environment Agency - Abu Dhabi (EAD)

Dr. John Burt, New York University (NYU)

Ms. Marina Antonopoulou, Emirates Wildlife Society (EWS) – WWF

Ms. Nessrine Alzahlawi, Environment Agency - Abu Dhabi (EAD)

Dr. Nicolas Pilcher, Marine Research Foundation

Mr. Obaid Al Shamsi, Ministry of Climate Change and Environment (MOCCAE)

Mr. Oliver Kerr, Emirates Wildlife Society (EWS) – WWF

Dr. Rima Jabado, Environment Agency - Abu Dhabi (EAD)

Dr. Robert Baldwin, Five Oceans Environmental Services LLC

Dr. Simon Wilson, Five Oceans Environmental Services LLC

Mr. Winston James Cowie, Environment Agency - Abu Dhabi (EAD)

We are additionally thankful for the participation, time and effort that multiple stakeholders across the region who participated in the multitude of meetings and dialogue. The authors would like to especially thank the following stakeholders for their particularly involved participation: Hassina Ali, Naoko Kubo, Reem Al Mheiri & Ahmed Al Hashmi - MOCCAE, Haifa Romdhane - Masdar Institute of Science and Technology (MIST), the EAD Marine team, Dr. Hassan Awad - Regional Organization for the Protection of the Marine Environment (ROPME), Humood Abdulla Naser - University of Bahrain, Dr. Jed Brown - Qatar University, Kathleen Russel - Al Mahara Dive Centre, Manya Russo & Paolo Ferreira - EWS-WWF, Maria Cordeiro - EAD, Mohamed El Tayeb - Dubai Municipality, Paula Anton FAO, as well as Suaad Al Harthi ESO.

About the Marine Biodiversity and Climate Change Sub-Project

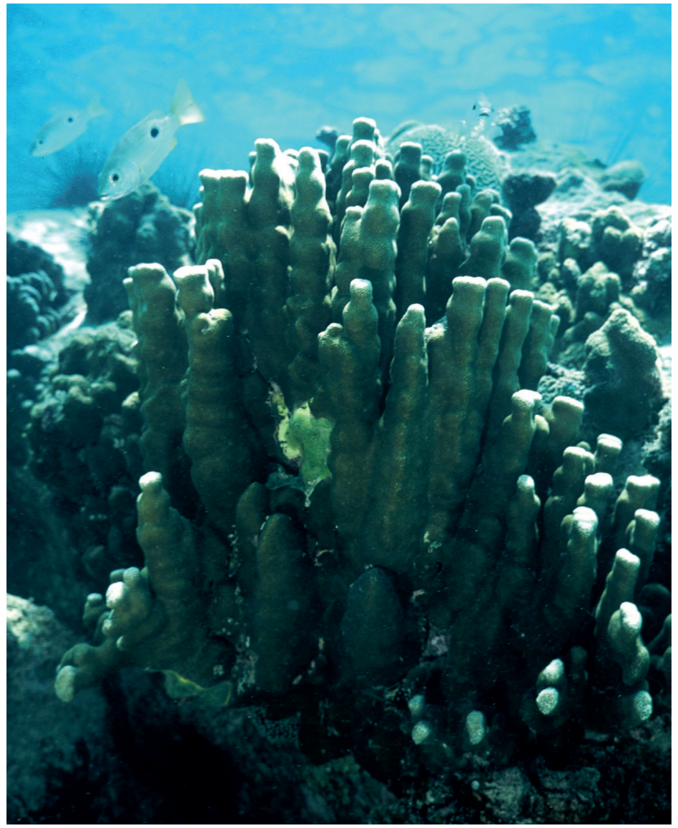
In October 2013, the Abu Dhabi Global Environmental Data Initiative (AGEDI) launched the "Local, National, and Regional Climate Change Programme (LNRCC) to build upon, expand, and deepen understanding of vulnerability to the impacts of climate change as well as to identify practical adaptive responses at local (Abu Dhabi), national (UAE), and regional (Arabian Peninsula) levels. The design of the Programme was stakeholder-driven, incorporating the perspectives of over 100 local, national, and regional stakeholders in shaping 12 research studies across 5 strategic themes. The "Marine Biodiversity and Climate Change" study within this Programme aims to assess the potential impacts and the vulnerability of marine biodiversity and fisheries in the Arabian Gulf to climate change.

1. Regional Marine Biodiversity Context

Marine biodiversity, ecosystem health and fisheries are currently threatened by overfishing, but also by pollution and other anthropogenic impacts (Pitcher and Cheung 2013).

Climate change further challenges our ability to devise sustainable management and conservation plans to maintain ecosystem services, as it has begun to alter ocean conditions, particularly water temperature and various aspects of ocean biogeochemistry (Gattuso et al. 2015). Marine biodiversity responds to shifting temperatures and other ocean conditions through changes in organismal physiology and phenology, as well as population dynamics and distributions (Pauly 2010; Poloczanska et al. 2013; Pörtner et al. 2014). These responses to ocean–atmospheric changes have been projected to lead to altered patterns of species richness (Cheung et al. 2009; Jones and Cheung 2015), changes in community structure (MacNeil et al. 2010), ecosystem functions (Petchey et al. 1999), and consequential changes in marine goods and services (Cheung et al. 2010; Sumaila et al. 2011; Madin et al. 2012).

Given the unique characteristics of the Arabian Gulf – particularly its extreme environmental conditions, the array of human disturbances it is exposed to, and the high sensitivity of its biota to environmental fluctuations as species are close to their environmental limits (Cheung et al. 2009; Buchanan et al. 2015) – climate change should have substantial implications for its marine ecosystems and fisheries. Extreme seasonal temperatures and salinity fluctuations select for species with high tolerance or adaptability to such short-term changes (e.g. as exhibited by some corals; see Kinsman 1964) creating a 'provincial barrier' for short-range endemics (Briggs 1974; Burt et al. 2011). Consequently, the Gulf is a region that is relatively species poor (Jones et al. 1978; Gray 2002; Coles 2003; Zolgharnein et al. 2010), at least in comparison with the open Indian Ocean (Coles 2003). However, as part of the Western Indian Ocean province of the Indo-West Pacific ecoregion (Spalding et al. 2007), which hosts a very distinct assemblage of species (e.g. 14.2% of fish in the Western Indian Ocean are endemics; Briggs and Bowen 2011), the Gulf is considered a biologically valuable region (see Olson and Dinerstein 1998).



The Arabian Gulf's marine ecosystems are currently being affected by a variety of human activities, including hydrocarbon pollution, wastewater, desalination of sea water, coastal development, and overfishing (Sheppard et al. 2010; Sale et al. 2011; Burt 2014; Naser 2014; Elhakeem and Elshorbagy 2015).

Additional declines have been caused by increases in sea surface temperature (SST) (e.g. Burt et al. 2013), with changes of +0.57°C recorded between 1950 and 2010 (Shirvani et al. 2014). Other climate change impacts that will affect the Arabian Gulf include ocean acidification, decline in oxygen content, sea level rise, increased UV exposure and, possibly, increases in extreme weather events. These changes are expected to impact marine organisms and the associated ecosystem goods and services we derive from them, such as fisheries.

Although many marine organisms in the Arabian Gulf have demonstrated high heat-tolerance relative to populations in other parts of the world (Sheppard 2003; Riegl et al. 2012; Hume et al. 2015; Hume et al. 2016), warming has already impacted some of the more vulnerable marine species in the region (Sheppard et al. 2010).

For example, corals have been exposed to major disturbances (Bento et al. 2016), including water temperatures between 35 and 37°C at least five times since the late 1990s, causing extensive coral bleaching (Coles and Riegl 2013) associated with considerable loss of coral cover (Grizzle et al. 2016). In 1996 and 1998, summer SST was 1.5 to 2.5°C above normal, with temperatures exceeding 36°C for 3 weeks. Stands of Acropora sp. were almost eliminated over 40 reefs along the coast of the United Arab Emirates (UAE) by 1999 (George and John 2000; Riegl 2002; Sheppard and Loughland 2002). Overall, about 70% of the Gulf's reefs have essentially disappeared in a few decades (Sheppard 2016) and this has been associated with a significant decline in fish species richness. While substantial declines in stress-sensitive species are expected with increasing temperatures, results from several long-term studies investigating benthic community structure across the region suggest that coral communities may persist within an increasingly disturbed future environment, albeit in a much more structurally simple configuration (Burt et al. 2008; Riegl et al. 2012; Bento et al. 2016).

2. Approach

The overall aim of this study was to provide a comprehensive assessment of the potential vulnerability of marine biodiversity and fisheries in the Arabian Gulf to climatic change.

This involved three major activities, (1) assessment of the status and trends for biodiversity and fisheries in the Arabian Gulf using local and internationally available data; (2) application of simulation modelling approaches to assess the climate change impacts to, and vulnerability of, selected marine biodiversity and fisheries that are considered priority species in the region; and (3) exploring the implications of these impacts for conservation and fisheries management policies for the region.

Study area

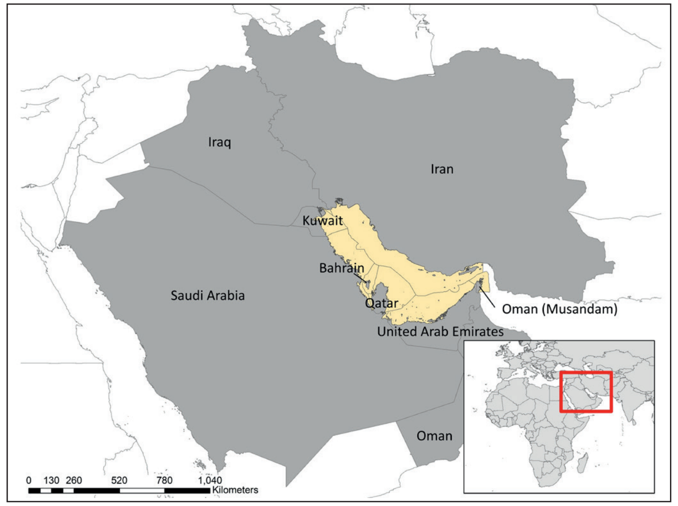
The focus of the study was the Arabian Gulf. Ecologically, the Gulf is a relatively shallow semi-enclosed sea with a depth range of 10 to 93 m, averaging 36 m, a length of 990 km, a width ranging between 56 and 370 km, and a total surface area of 239,000 km^2 (see Figure 1). It has a gently sloping terraced shelf punctuated by numerous islands that formed as part of an extensive sabkha (i.e. salt flat see Al-Farraj 2005). Primary productivity is high at certain times of the year, with an increasing gradient in phytoplankton species richness and biomass from the Shatt Al Arab area (low species diversity, high biomass and production) to Kuwait, the Gulf of Oman, and the Strait of Hormuz (high species diversity, low biomass and production; see Subba Rao and Al-Yamani 1998).

Priority species

The focus of the effort was on a set of priority species, as identified by stakeholders and informed by data availability.

This involved developing a list of species for which to seek data records for subsequent modelling. A consultative approach was used whereby 1) feedback from local specialists was obtained regarding priority species; 2) existing literature and published assessments of those species were examined; and 3) the availability of all other local and internationally available occurrence records were investigated. As a result of this process, a total of 55 priority species were selected, encompassing the most important commercial fish species (47), charismatic species (5), and seagrass species (3). It is important to note that this represents small subset of the thousands of fish species in the Gulf. Table 1 provides a list of priority species considered

Figure 1: The Arabian Gulf study region



Environmental data availability

Marine biodiversity, distribution, and biology data for the Gulf was extracted from FishBase (www.fishbase.org) and SeaLifeBase (www.sealifebase.org) after enriching these databases with local data from stakeholders.

Specifically, updates were preformed regarding the coverage of all aspects of the species' biology making up its ecosystems, focusing on the 55 priority species, based on feedback with stakeholders. Other environmental data were obtained from a variety of sources. Species presence/occurrence data were obtained from the Ocean Biogeographic System (OBIS, http://www.iobis.org, accessed in 2015) and the Global Biodiversity Information Facility (GBIF, http://www.gbif.org/). All points deemed erroneous were removed based on known environmental preferences and geographic limits.

Fisheries catch reconstructions

Fishery catch reconstructions for each country in the Gulf region from 1950 to 2010.

These reconstructions provided estimates for all fisheries sectors and components by country. A detailed methodology was applied to project country-wide catch estimates, as described in the Final Technical Report. These fish reconstructions represented a fundamental starting point for the modelling of climate change impacts on commercial fisheries.

Climate change forecasts

The vulnerability assessment incorporated information of current and future conditions in Gulf waters.

For current conditions in the Gulf, environmental parameters known to influence marine species distribution were gathered at a global gridded scale, including sea surface/bottom temperature, salinity, nutrient concentrations from the World Ocean Atlas. For conditions in the Gulf under climate change, outputs from the LNRCCP's regional ocean modelling sub-project were used for the current (2000-2020) and future (2080-2100) periods (Edson et al. 2015) based on Representative Concentration Pathway (RCP) 8.5 which reflects a high greenhouse gas emissions (or business-as-usual) scenario.

Climate change impact modelling framework

The current and future distributions of the prioritized 55 marine species were modelled using an environmental niche approach.

This method quantifies the environmental preferences of marine species and projects their potential distribution according to present and future environmental conditions. The environmental niche of each species was quantified using three separate models: the Non-Parametric Probabilistic Ecological Niche (NPPEN) model (Beaugrand et al. 2011); the Bioclimate analysis and prediction (BIOCLIM) model (Busby 1991), and the Ecological Niche Factor Analysis (ENFA) model (Hirzel and Arlettaz 2003). From these models' quantification of projected changes in distributions, climate change impacts were estimated by using four indicators: rate of species invasion, rate of species local extinction, and sum of habitat suitability. Using three models rather than relying on a single one provides a way to bracket uncertainty in the results.

Table 1: The Arabian Gulf study region

#	Species	Name
1	*Acanthopagrus bifasciatus*	Twobar seabream
2	*Acanthopagrus latus*	Yellowfin seabream
3	*Argyrops spinifer*	King soldier bream
4	*Auxis rochei*	Bullet tuna
5	*Caranx ignobilis*	Giant trevally
6	*Carcharhinus sorrah*	Spot-tail shark
7	*Chanos chanos*	Milkfish
8	*Chiloscyllium griseum*	Grey bambooshark
9	*Chirocentrus nudus*	Whitefin wolf-herring
10	*Coryphaena hippurus*	Common dolphinfish
11	*Epinephelus coioides*	Orange-spotted grouper
12	*Gerres oyena*	Common silver-biddy
13	*Gnathanodon speciosus*	Golden trevally
14	*Leiognathus equulus*	Common ponyfish
15	*Lethrinus lentjan*	Pink ear emperor
16	*Lethrinus nebulosus*	Spangled emperor
17	*Liza klunzingeri*	Klunzinger's mullet
18	*Lutjanus johnii*	John's snapper
19	*Metapenaeus monoceros*	Bluespot mullet
20	*Moolgarda seheli*	Japanese threadfin bream
21	*Nemipterus japonicus*	Giant catfish
22	*Netuma thalassina*	Tigertooth croaker
23	*Otolithes ruber*	Silver pomfret
24	*Pampus argenteus*	Black pomfret
25	*Parastromateus niger*	Fourlined terapon
26	*Pelates quadrilineatus*	Donkey croaker
27	*Penaeus semisulcatus*	Bartail flathead
28	*Pennahia anea*	Javelin grunter
29	*Platycephalus indicus*	Striped piggy
30	*Pomadasys kaakan*	Indian halibut
31	*Pomadasys stridens*	Cobia
32	*Portunus segnis*	Indian mackerel
33	*Psettodes erumei*	Haffara seabream
34	*Rachycentron canadum*	Indian oil sardine
35	*Rastrelliger kanagurta*	Black-streaked monocle bream
36	*Rhabdosargus haffara*	Narrow-barred Spanish mackerel
37	*Sardinella longiceps*	Indo-Pacific king mackerel
38	*Scolopsis taeniata*	Bigeye scad
39	*Scomberomorus commerson*	Yellowstripe scad
40	*Scomberomorus guttatus*	Great barracuda
41	*Scomberomorus lineolatus*	Hilsa shad
42	*Selar crumenophthalmus*	Largehead hairtail
43	*Selaroides leptolepis*	Sulphur goatfish
44	*Sphyraena barracuda*	Starry triggerfish
45	*Tenualosa ilisha*	Hilsa shad
46	*Trichiurus lepturus*	Flat needlefish
47	*Upeneus sulphureus*	Scissortail sergeant
48	*Chelonia mydas*	Green sea turtle
49	*Dugong dugon*	Dugong
50	*Eretmochelys imbricata*	Hawksbill turtle
51	*Sousa chinensis*	Pacific humpback dolphin
52	*Tursiops aduncus*	Indian Ocean bottlenose dolphin
53	*Halodule uninervis*	Needle seagrass
54	*Halophila ovalis*	Spoon seagrass
55	*Halophila stipulacea*	Broadleaf seagrass

3. Climate change impact on commercial fish species

For each of the 47 priority fish species, the rate of species invasion, rate of species local extinction, and sum of habitat suitability under climate change were modelled using the NPPEN, ENFA, and BIOCLIM models.

Hence, a large number of maps were developed, detailed results of which are available in the annexes of the Final Technical report. Access to the various databases used to construct the maps as well as the maps themselves are available online at the Marine Biodiversity & climate change Inspector (www.ccr-group.org/marinebiodiversity).

Climate change is projected to have significant adverse impacts on commercial fisheries in the Gulf.

This is illustrated in Figure 2 which shows the impacts of climate change on species richness (left) and habitat suitability (right) for the set of 47 priority species as obtained from the three modelling frameworks. The models project a high rate of local extinction (areas in red) in the Arabian Gulf by 2090 relative to 2010 under the RCP 8.5 scenario. Spatially, local extinction is highest in the southwestern part of the Arabian Gulf, off the coast of Saudi Arabia, Qatar and the UAE. In contrast, species invasion (areas in blue) is limited to small areas in the northern part of the Arabian Gulf, off the coast of Kuwait and northern Iran. There is general agreement for these conclusions across all three models' results.

Climate change may render most of the southern Gulf unsuitable for species making up current biodiversity.

In the future, only species with extreme adaptability particularly with regards to temperature, are likely to occur in this area. Nonetheless, variability in the projections between models is visible for portions of the central Arabian Gulf. Climate-driven impacts on local and regional environmental conditions will make most of the southern Gulf potentially unsuitable for species making up current biodiversity. The projected habitat suitability increases in the northern part of the Gulf, potentially providing the only refuge for fauna in the Gulf.

Since most fish species in the Gulf are either highly adapted or at the edge of their environmental ranges, their sensitivity to any environmental or habitat perturbation is likely to be high.

Thus, it is not surprising that projections of local species extinctions driven by temperature change are high. Model results showed that under climate change, species' ranges would shift poleward, from the eastern part of the Gulf to the coast of Iraq and Iran by 2090. As species' northern expansion/range is limited by land, the scope for these to adapt to warming through a poleward range shift is limited. Such a cul-de-sac effect would increase the overall rate of local extinctions in the Gulf and has been projected to occur in other semi-enclosed seas such as the Mediterranean (Ben Rais Lasram et al. 2010).

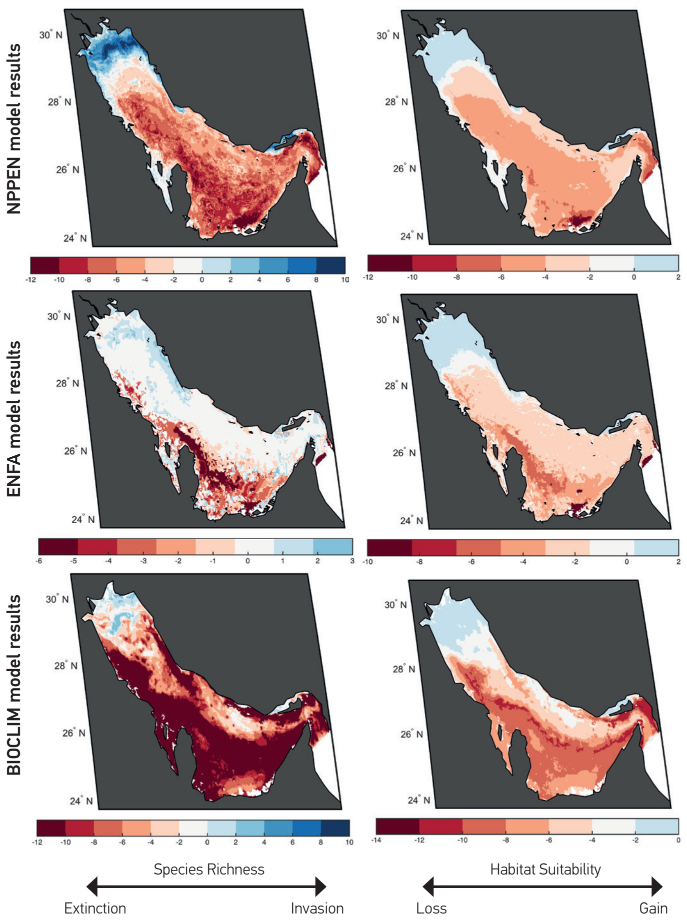
Results also showed that a decline in species habitat suitability translates directly into a projected decrease in maximum fisheries catch potential, particularly along the southwestern parts of the Gulf.

The results of the modelling effort were integrated into a vulnerability assessment framework that included indicators for countries' socio-economic sensitivity and adaptive capacity. Findings from this assessment showed that those nations most vulnerable to climate change impacts on fisheries were not confined to the southwestern coast, but also included Iran and Iraq. By integrating the ecological results of climate change impacts on marine biodiversity into a more comprehensive socio-economic framework, this study's findings highlight the value of such an analysis (i) to better inform the adaptation process and (ii) to assist national economies and societies to better anticipate, and prepare for adaptive mechanisms to cope with, climate change impacts so that efforts can be focused and prioritized.

Finally, it is important to note that the environmental niche models applied in this study assume that species' traits do not evolve as environmental conditions change.

However, species may well adapt to warming through genetic or transgenerational adaptations (e.g. Hume et al. 2016). Nevertheless, the extent of such adaptive responses may be limited, as postulated from the substantially lower species diversity in the Arabian Gulf relative to the adjacent Indian Ocean where conditions are not as extreme. The time frame over which they would have to evolve given the pace at which climate change is advancing may also be too short. In addition, these projections do not include trophic interactions among species or how other human impacts such as changes in fishing effort may influence species' presence and distribution as well as biodiversity patterns.

Figure 2: Projected changes in species richness (left) and habitat suitability (right) for the 47 priority fish species by 2090 relative to 2010 under RCP8.5



4. Climate change impact on charismatic species

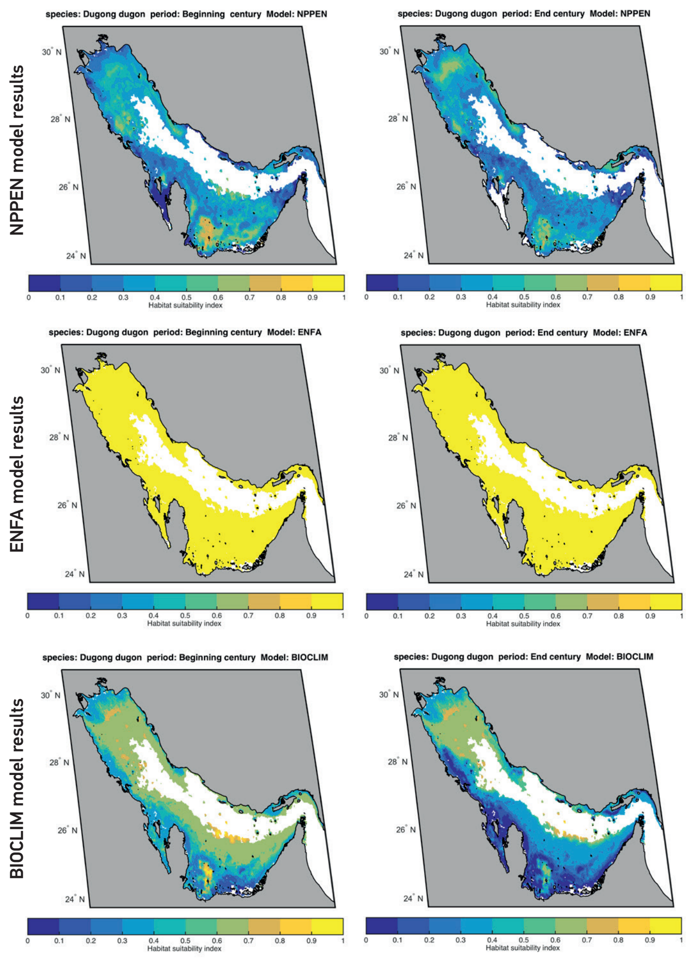
For each of the 5 charismatic species, habitat suitability under climate change were modelled using the NPPEN, ENFA, and BIOCLIM models.

Detailed results are available in the annexes of the Final Technical report. Access to the various databases used to construct the maps as well as the maps themselves are also available online at the Marine Biodiversity & climate change Inspector. While models showed varying ranges of loss in habitat suitability for dugong, sea turtles and Indo-Pacific dolphin in the Gulf, overall, future projections were largely inconclusive.

For dugongs, the Arabian Gulf is currently the major remaining habitat, after Northern Australia.

Projections from the BIOCLIM and NPPEN models showed that the Gulf would become less hospitable to dugong, particularly around the southwestern region such as the waters around Bahrain (see Figure 3). Habitat suitability for given species scales from 0 to 1, with 0 (blue) being not suitable and 1 (yellow) most suitable. An increase in blue areas for the NPPEN and BIOCLIM model indicate a loss of habitat suitability. However, habitat suitability predicted by the ENFA model, the least conservative among the three models, showed essentially no loss of habitat suitability for dugongs under climate change. It is important to note that all results show future modelled habitat suitability in the region according to projected changes in temperature and salinity relative to the preferred environmental niche of the marine mammal itself. Consequently, these projections do not take into account the fact that dugongs rely on seagrass for almost their entire diet, and the likely resultant changes in dugong's habitat suitability based on projected changes to seagrass distribution.

Figure 3: Current and projected habitat suitability of dugong in the Arabian Gulf under RCP 8.5



For green and hawksbill turtles, projections from BIOCLIM and NPPEN showed a loss of habitat suitability around the southwestern parts of the Gulf and near the Strait of Hormuz.

The NPPEN additionally shows loss of habitat in the northern parts of the Gulf. Findings from the ENFA projections agree with these results, but the loss of suitable habitat in the south and southwestern Gulf were more severe. The projected patterns of changes in habitat suitability are similar between green and hawksbill turtles, except that NPPEN projects a more substantial habitat loss for green turtles along the Gulf coast. Post-nesting tracks of 90 turtles showed these areas to currently be the most important for this species in the Arabian region (Pilcher et al. 2014). Overall, the highly migratory nature of marine turtles, and their ability to move considerable distances in short periods of time, should increase their resilience to climate change. In the context of the Arabian Gulf, this may mean that turtles may come to spend less time in the region.

For Indo Pacific dolphins, habitat suitability, the model projections showed loss of habitat suitability particularly around the southwestern parts of the Gulf, and extending to Bahrain and Qatar.

All three environmental niche models project large declines in habitat suitability of bottlenose dolphin for most areas in the Gulf, except for the northern Gulf region. Changes other than sea temperature, such as key forage species, are likely to be more significant in determining dolphin vulnerability to climate change. In the future, their distribution may shift in accordance with changes in the habitat suitability of their key prey.

5. Conclusions and recommendations

Marine biodiversity was found to be particularly vulnerable to climate change impacts along the south and southwestern coasts of the Gulf, and efforts should probably prioritise these areas.
Multiple human stressors, such as habitat destruction and overfishing, are likely to exacerbate this vulnerability. Effective management of activities in the Arabian Gulf under climate change is likely to increase the resilience of ecosystems and the adaptive capacity of policy-making systems, for example by reducing other human impacts, to ensure the sustainable flow of ecosystem services into the future.

Impacts of climate change on marine biodiversity can be moderated by reducing stresses from overfishing and destructive fishing practices; habitat degradation; pollution and runoff; oil and gas exploration; land-use transformation, land reclamation and sedimentation; as well as invasive species.
Therefore, effective implementation of ecosystem-based management that considers a much wider range of environmental and human stressors is fundamental to increasing the adaptive capacity of marine social-ecological systems to climate change. This includes strengthening the implementation and enforcement of current regulations and agreements to protect marine resources in the Arabian Gulf.

Adaptive marine conservation and management are important in uncertain future ocean ecosystems.
The reduced predictability of marine ecosystems due to climate change will make it more difficult to provide accurate assessments of the current and future status of marine biodiversity. Also, changing baseline oceanographic and ecological conditions may affect the effectiveness of existing conservation and management measures such as marine protected areas (MPAs). Monitoring programmes that are designed for a changing ocean and that incorporate collected data as well as adapt to analyses' findings are thus critical to adaptive systems. Monitoring will include data for indicators at the pressure, state, and response levels, thereby promoting fast decision responses to changing and uncertain conditions and allowing a suite of possible responses to be maintained. However, the potential for mal-adaptation and trade-offs from multiple adaptation actions should also be evaluated.

While MPAs certainly do not offer a panacea for climate change impacts on biodiversity and fisheries in the Gulf area, they are regarded as an important tool for the sustainable management and conservation of marine biodiversity, and have been shown to enhance population resilience to climate-driven disturbances.
However, climate change induced changes in environmental suitability and resulting species' distribution shifts may lead to both emigration and immigration of species from or into an MPA. Therefore, it will be important to have a closer look at existing MPAs and what threats they face, to devise and implement measures to mitigate these, particularly for MPAs that emerge as critical in the future. Existing and proposed MPAs should be associated with comprehensive management plans for them to be effective.

The sooner precautionary measures directly targeting fisheries effort (particularly in countries most affected by changes in catch potential) that take into consideration future changes are taken, the smoother the transition will be.
Such considerations should involve wide-scale local stakeholder involvement at all levels to raise awareness and empower communities to aid in proposing solutions to tackle the required changes. Reducing compounding stresses will also help further ensure the sustainable flow of ecosystem services into the future.

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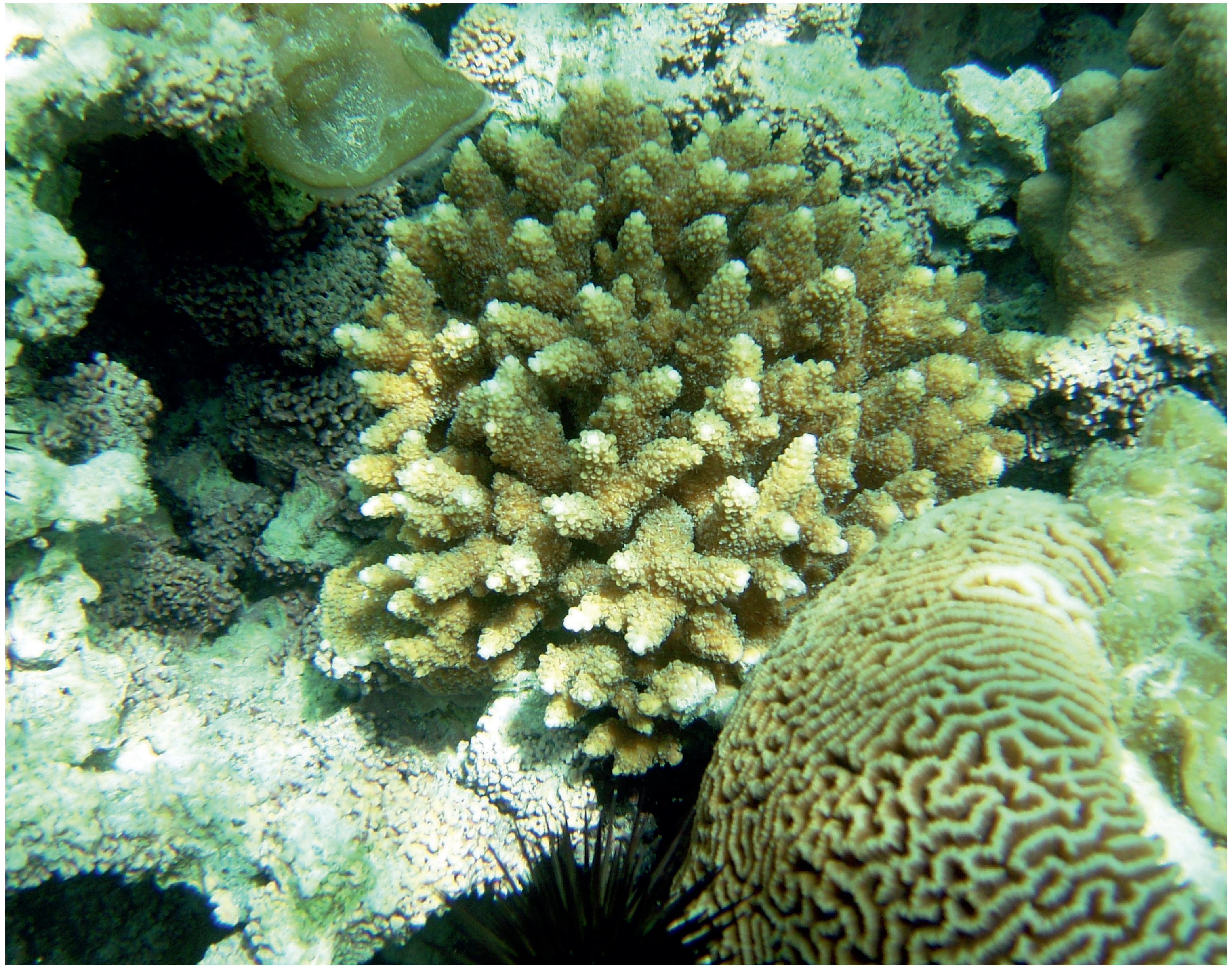

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About

AGEDI

Under the guidance and patronage of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the United Arab Emirates, the Abu Dhabi Global Environmental Data Initiative (AGEDI) was formed in 2002 to address responses to the critical need for readily accessible, accurate environmental data and information for all those who need it.

With the Arab region as a priority area of focus, AGEDI facilitates access to quality environmental data that equips policy-makers with actionable, timely information to inform and guide critical decisions. AGEDI is supported by Environment Agency – Abu Dhabi (EAD) on a local level, and by the United Nations Environment Programme (UNEP), regionally and internationally.

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The Environment Agency - Abu Dhabi

The Environment Agency – Abu Dhabi (EAD) was established in 1996 to preserve Abu Dhabi's natural heritage, protect our future, and raise awareness about environmental issues. EAD is Abu Dhabi's environmental regulator and advises the government on environmental policy. It works to create sustainable communities, and protect and conserve wildlife and natural resources. EAD also works to ensure integrated and sustainable water resource management, to ensure clean air and minimize climate change and its impacts.

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