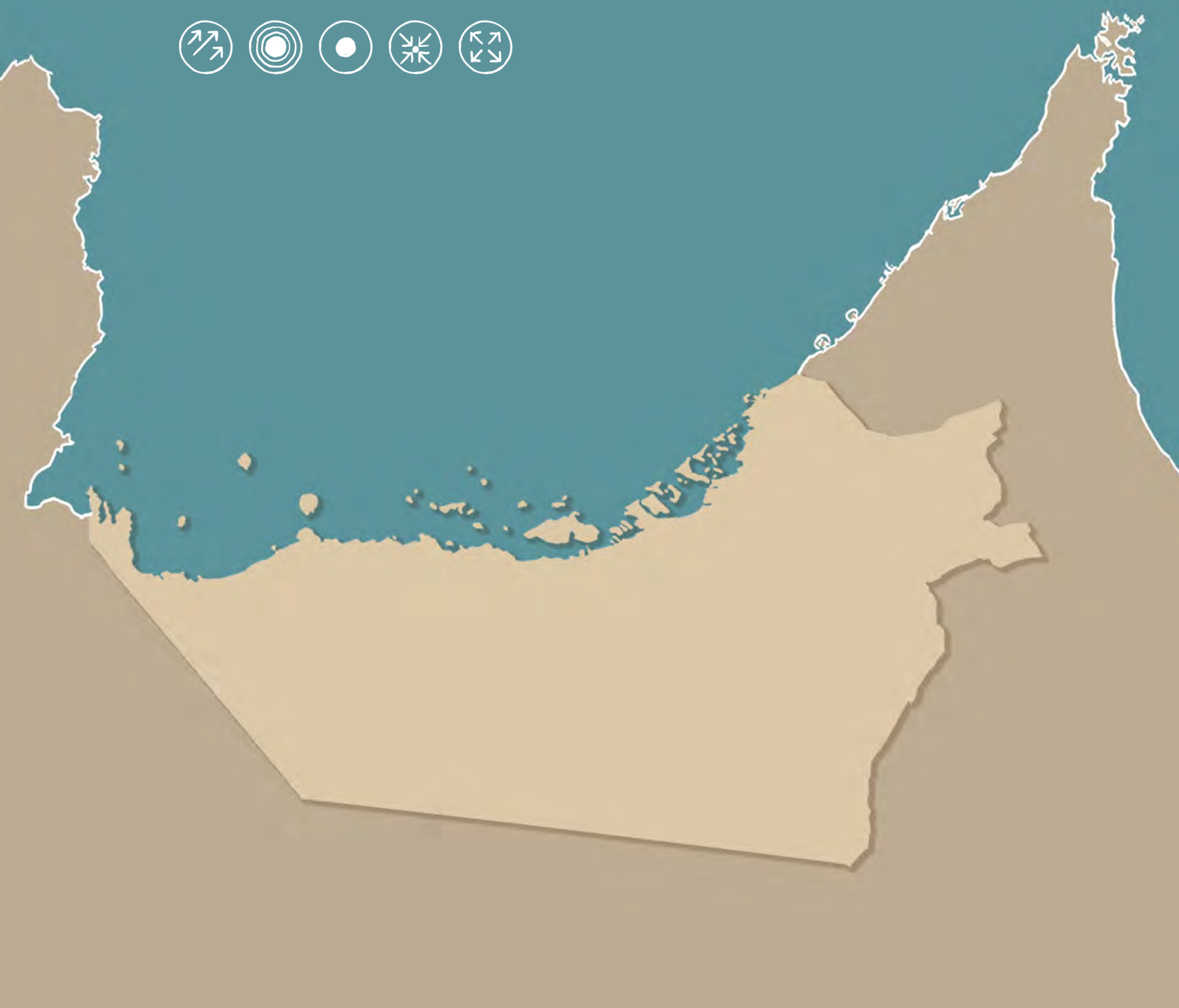
عاماً من الحماية
YEARS OF PROTECTION

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

ABU DHABI STATE OF ENVIRONMENT REPORT 2017



ABU DHABI STATE OF ENVIRONMENT REPORT 2017

هـيـئـة الـبـيـئـة - أبـوظـبـي
Environment Agency - ABU DHABI

20 عاماً من الحماية
YEARS OF PROTECTION

Contents

H.H. HAMDAN BIN ZAYED AL NAHYAN

Foreword

The Emirate of Abu Dhabi has experienced unprecedented growth over the last 40 years. Since 1975 the population has grown over 14 times, and in the past decade alone it has almost doubled. Our GDP has similarly grown exponentially.

Our emirate and our nation should be justifiably proud of this progress. We are indebted to the leadership of our President HH Sheikh Khalifa bin Zayed Al Nahyan and HH Sheikh Mohamed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces, who are guiding the rapid and sustained development of our emirate.

But not surprisingly, with this development there has been greater industrialisation, urbanisation, use of technology, transportation, and an increase in our appetite for consumables, water and energy. All of these factors have the potential to impact our fragile natural environment negatively. We believe that our continued growth must be sustainable, and for this to happen, a frank and realistic view of the current state of our environment and of significant human impacts is essential. Only then can we make policy decisions to chart a more sustainable path for growth. This robust State of Environment Report has been developed using global best practices and knowledge. It has been authored by UAE nationals, ensuring transfer of knowledge and ownership of methods for future environmental reporting.

This report will prove a useful resource for the decision-makers of our emirate and beyond. It will be an intrinsic part of the programme and strategy development to meet the goals laid out in the Abu Dhabi Plan, which seeks to chart a course for a more sustainable emirate for all inhabitants of Abu Dhabi, economically, socially and environmentally, with far-reaching benefits to the global community.

This report will form the baseline from which to develop better environmental monitoring and sustainable practices for the future. We enthusiastically encourage all entities from the Government and Private sector to use this resource in their environmental considerations and planning. We also commit to making environmental information freely and widely available to all entities to encourage a greater, collaborative effort in environmental planning for the benefit of current and future generations.

HAMDAN BIN ZAYED AL NAHYAN
Ruler's Representative in Al Dhafra Region
Chairman of Environment Agency – Abu Dhabi

H.E. MOHAMMED AHMED AL BOWARDI

Preface

Today our planet faces potentially very grave consequences resulting from the growth of the global population and our appetite for resources. Issues such as climate change, water scarcity and food security weigh heavily on our collective consciousness. Thankfully, there is a growing global movement towards environmental protection and preservation. Many governments, corporations and citizens are actively pursuing and reaping the benefits of a green growth strategy, striving not only to limit the anthropological impacts of our continued development but, where possible, to reverse the trends of environmental degradation. The leadership of Abu Dhabi and the federal government of the United Arab Emirates are determined to be leaders and not followers in environmental stewardship.

We have made commitments to international agreements and instruments to this end: the Paris Agreement on Climate Change, the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Flora & Fauna (CITES), and the Minamata Convention on Mercury, to name a few. We also are enthusiastic signatories to the United Nations Sustainable Development Plan and the implementation of its goals and targets.

But perhaps our biggest commitment is to the people of Abu Dhabi. The vision for Abu Dhabi, enshrined in the Abu Dhabi Plan, is to deliver sustainable growth for the benefit of all inhabitants of the emirate. The Plan, developed under the guidance of HH Sheikh Mohamed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi, aims to deliver the vision of HH Sheikh Khalifa bin Zayed Al Nahyan, President of the UAE, Ruler of Abu Dhabi, for the continued fulfilment of the grand design envisaged by the late Sheikh Zayed bin Sultan Al Nahyan.

But such international commitments and sustainability targets can only be met with a thorough understanding of the state of the environment and of priority issues that we face – whether they are natural or anthropological. This State of Environment Report, prepared by the Environment Agency – Abu Dhabi (EAD), paves the way for an honest, open revelation of the issues and a subsequent dialogue with policy-makers as the first step in finding workable, sustainable solutions.

The development of the State of Environment Report not only consolidated our collective knowledge on the environment, but it also built capacity among the employees of EAD, like-minded entities, and local and international peer reviewers. It has also been an exercise in gap analysis, for there is clearly a constant need to seek in-depth data and robust analysis on the state of our environment and priority areas if we are to effect change for good. We actively encourage readers to utilise the data contained here and where possible to contribute further to environmental understanding and policies that will help shape a better future for all.

MOHAMMED AHMED AL BOWARDI
Minister of State for Defence Affairs
Managing Director of Environment Agency – Abu Dhabi

H.E. RAZAN KHALIFA AL MUBARAK

Message

The Environment Agency – Abu Dhabi is celebrating, reflecting and building upon 20 years of achievement in environmental protection in the Emirate of Abu Dhabi. The cornerstone of all of our achievements is the collection, interpretation and utilisation of environmental data. This enables us to continue our efforts in species conservation, habitat protection, the designation of protected areas and in environmental quality-related issues. We champion the improvement of marine water quality and air quality, and the protection of precious groundwater resources. And we continue to further our understanding of the potential impacts of climate change and how to mitigate against these, and to develop appropriate policy instruments and a judicial system to ensure their enforcement.

None of these achievements would have been possible without an ever-deepening understanding of the state of our environment. Perhaps one of our biggest accomplishments over the past 20 years is the growth of our collective knowledge on the state of our environment and anthropogenic impacts.

The creation of the 2017 State of Environment Report for the Emirate of Abu Dhabi is the culmination of that knowledge. We have chosen the internationally recognised DPSIR model (Drivers, Pressures, State, Impacts, and Responses) to frame our knowledge on the state of the environment and to demonstrate the interrelation and consequences of environmental pressures.

The State of Environment Report is a snapshot at a point in time. However, our collection, aggregation and analysis of data, and the way that we use this collective knowledge, is a continuum. Where there are gaps in data or understanding we will seek to fill them. We strive to make better use of our collective knowledge for cohesive action to develop and enforce stronger policy instruments for environmental preservation, for the benefit of our natural environment and the inhabitants of Abu Dhabi Emirate.

RAZAN KHALIFA AL MUBARAK
Secretary General of Environment Agency – Abu Dhabi

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INTRODUCTION

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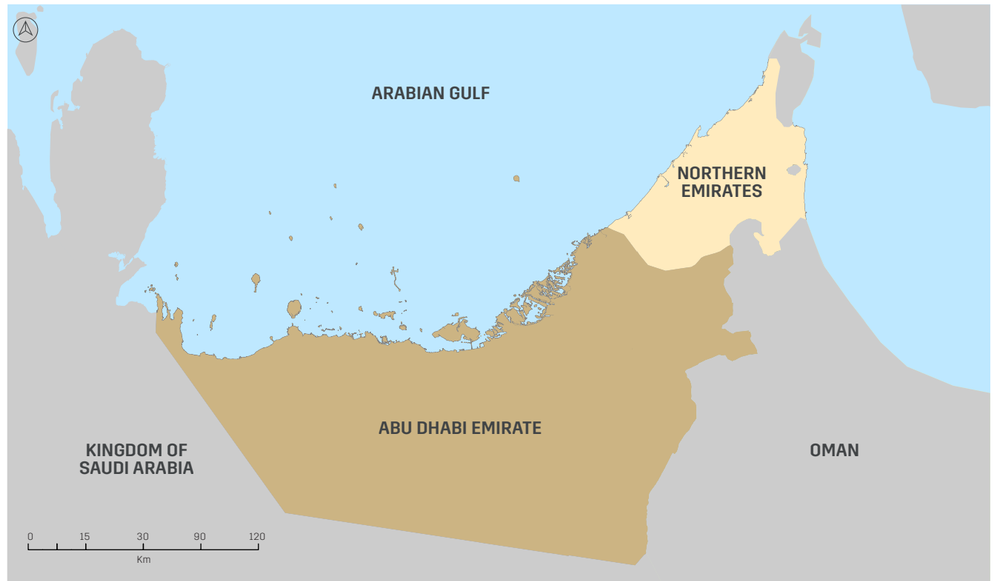
1 About Abu Dhabi Emirate

Abu Dhabi is the capital emirate of the United Arab Emirates (UAE), a young federation of seven emirates which was founded in 1971. The largest of the emirates, Abu Dhabi covers around 67,000 km², accounting for 87 % of the area of the UAE, and is home to 2.7 million inhabitants, almost 30 % of the UAE population [1].

Abu Dhabi is bordered by the Arabian Gulf and the Emirate of Dubai to the north, the Kingdom of Saudi Arabia to the west and south, and the Sultanate of Oman to the east (see Map 1.1). The emirate's climate is arid, with a sub-tropical climate that is hot in summers and mild to cool in winters with sporadic rainfall [2].

Abu Dhabi Emirate has a rich natural heritage. Its varied geology of mountains (rising above 2,000 m in the east), sandy desert, wadis and salt flats ('sabkha') create the conditions for a diverse range of habitats, reflected in a rich variety of plants and animals.

MAP 1.1 Abu Dhabi Emirate



SOURCE: EAD

1.1 Abu Dhabi's Commitment to the Environment

Abu Dhabi Government is committed to preserving the emirate's environment and natural resources in order to maintain the wellbeing of its people and the strength of its economy for present and future generations. This commitment has been reflected in the Abu Dhabi Plan, which is the emirate's strategic blueprint designed to guide its development and sustainable growth. It has 25 key goals, one of which is to achieve 'a sustainable environment and the optimal use of resources to preserve natural heritage'.

To achieve the stated goals of the Abu Dhabi Plan, a range of programmes across all vital sectors is to be implemented between 2016 and 2020. Five of these programmes relate to the environment:

- Improving marine water quality;
- Improving air quality and limiting the impacts of climate change;
- Preserving biodiversity, fisheries and soil resources;
- Managing waste;
- Managing water resources, including groundwater.

Achieving this vision for sustainable development requires a delicate balance. As the economy grows, so does demand for energy, water and other raw materials. Much of this raw material will have to be imported, which increases the environmental impacts associated with sea and land transport. Levels of carbon dioxide (CO_2) and other gaseous emissions are likely to increase from the manufacturing processes, as well as the transport of raw materials and end produce. The volume of waste (including hazardous waste) will also increase, requiring safe treatment or storage.

The availability of water in Abu Dhabi Emirate is a particular and urgent concern. Currently the majority of water used comes from groundwater, with the remainder provided through desalination and recycled water. However, groundwater replenishes slowly in this arid environment, causing the supply to diminish. Abu Dhabi Emirate's growing population means a future need for increased water supplies. As groundwater levels diminish, more reliance will be placed on desalination processes, which are energy- and carbon-intensive.

Globally, the climate is also changing. Increased greenhouse gas (GHG) emissions are seeing temperatures getting hotter, with melting ice caps and glaciers causing sea levels to rise. This will put further pressure on vulnerable areas, such as the coastal zone, which is already under pressure from development. The mangrove forests and seagrass meadows in Abu Dhabi Emirate will be affected by the increase in sea levels and water temperatures. A rise in sea temperature will also result in more cases of coral bleaching, as increased temperatures kill off the algae (*zooxanthellae*) that lives in a symbiotic relationship with the coral, giving it its distinct colour. Fish stocks in the Gulf are already under pressure, which will only increase if the quality of marine habitats deteriorates at the same time as a growing human population increases the demand for fish products.

As Abu Dhabi Emirate continues to develop, it is critical that a strong and effective environmental regulatory framework is in place, with strategy focusing on the big issues in partnership with government, NGOs, academia and the private sector. This regulatory and strategic approach must be based on a good understanding of the state of the environment and longer-term trends. This document is intended to be used by leaders, regulators and policy makers to facilitate future economic growth while protecting and enhancing the environment.

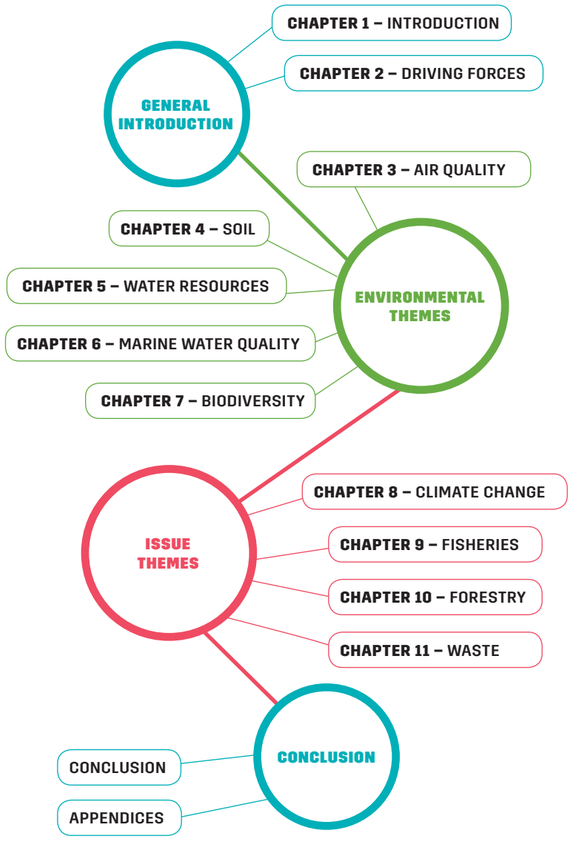
1.2 About this Report

Overview

Typically, state of environment reporting provides a periodic (five-yearly) assessment of the environment, covering a wide range of themes such as air, water, land and biodiversity.

This current Abu Dhabi State of Environment Report (AD-SoER) has been developed to cover the main environmental themes as well as several key issues facing the emirate (see Figure 1.1). While it is recognised that there is no clear divide between issues and environment, there are four issues that deserve a separate mention, namely: climate change, fisheries, forestry and waste.

FIGURE 1.1 Structure of AD-SoER



Objectives

The objectives of AD-SoER (2017) are:

- To assess and understand the state of the environment and changes in trends over the past five years.
- To strengthen evidence-based decision-making towards achieving sustainable management across different sectors, as well as for whole-of-government plans such as the Abu Dhabi Plan.
- To assist in identifying environmental data and policy gaps as well as opportunities to improve.
- To increase awareness around the state of the environment and issues among governmental bodies, private companies and people.
- To build capacity in areas including environmental assessment, stakeholder engagement and quality assurance.

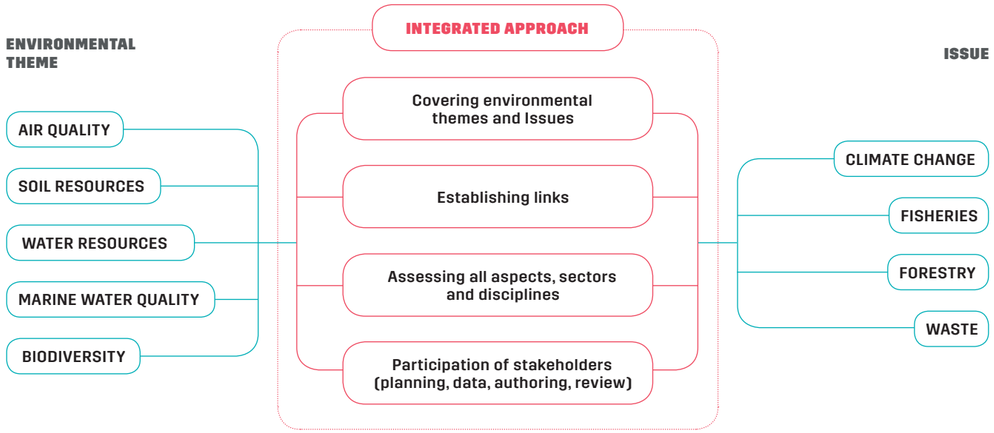
Approach

When developing the AD-SoER, it was essential to use an integrated approach that covers not just all of the different environmental themes and issues, but also looks at relationships between themes and assesses each from all aspects, through the collaboration, analysis and review of all stakeholders (see Figure 1.2).

Interlinked Overview Between Themes

The environment comprises various components, as is reflected in the environmental themes and issues. These components often closely affect and interact with each other: within the report links between chapters are highlighted.

FIGURE 1.2 Integrated Approach Used in AD-SoER 2017



DPSIR Framework

To achieve an integrated environmental assessment, this report uses the DPSIR framework (Drivers – Pressures – State – Impact – Responses), as recommended by the European Environment Agency (EEA) [3] to map socioeconomic activities with environmental change.

Using the DPSIR framework (see Figure 1.3) helps structure the assessment, and by drawing cause-effect relationships allows the following to be assessed:

Drivers The primary forces driving environmental change, namely social, demographic, legal, policy and economic developments and the corresponding changes in lifestyles, consumption and production patterns

Pressures The human and natural factors causing environmental change

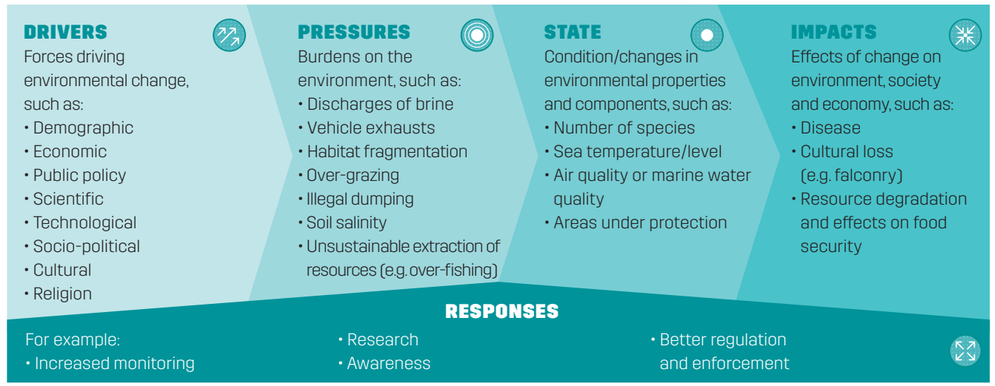
State The physical, chemical or biological conditions and trends of the environment

Impact The implications of environmental change on society's welfare, through the effects of those changes on ecosystems, human health and the economy

Responses The responses from organisations and individuals to address this change and their effectiveness

The DPSIR scheme in this report provides an overview of each environmental theme, as well as its links with other themes. When applying the framework, the environment, economy and society were considered to achieve an integrated approach.

FIGURE 1.3 DPSIR Model



Stakeholder Participation

The development of AD-SoER 2017 was led by the Environment Agency – Abu Dhabi (EAD), and the report went through multiple layers of stakeholder participation and consultation. The purpose of this was fourfold:

1) To clarify users' expectations and ensure results are relevant for policy- and decision-making.
2) To collect information and data that may not be available in the public domain.
3) To foster common understanding of complex issues and solutions, especially when there is uncertainty and weak data.
4) To provide scientific credibility, accuracy and legitimacy.

AD-SoER 2017 development team members come from multiple fields of expertise and backgrounds. Compiling the report combined the internal work of different departments and sections throughout EAD, and included project management, knowledge management, data management, communications, capability building and stakeholders' management, as well as authoring and internal reviews. Each chapter of the report has been led by an Emirati author alongside contributing authors from the Agency.

In addition, effective stakeholder engagement enabled EAD to understand and manage external stakeholders' expectations and contributions, share a common vision, and get their buy in. Representing Emirate entities, federal entities, NGOs and academia, this took place at various stages of the report process, including planning, collecting data and information, and peer review, as well as workshops and bilateral meetings.

Looking Forward

EAD is committed to the search for better assessment tools and methods to monitor and report the state of our environment. Each time this report is developed it serves to further the pursuit of fact-based policy formulation and decision-making, in order to sustain the environment for present and future generations. During the development of AD-SoER 2017, a new generation of young Emiratis was trained for future production and assessment. Infused throughout the process, capability-building for young Emiratis included: author training sessions; the involvement of younger Emirati national experts in all aspects of the report's development to allow knowledge transfer and learning as they worked; and the establishment of effective knowledge management for future experts to use as a foundation for their work.

DRIVING FORCES OF ENVIRONMENTAL CHANGE

LEAD AUTHOR – SHEIKHA AL MAZROUEI
Director – Environment Strategy Performance & Implementation Supervision
Integrated Environment Policy & Planning
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KEY MESSAGES

DRIVERS

Increasing demand for natural resources (air, water, soil, fuels, minerals and biodiversity) and increasing pollution (emissions, effluents and waste) create pressure on the environment. Common drivers for these pressures include population growth, economic development, lifestyle and choice of technology.

Abu Dhabi Emirate has achieved notable success in its demographic and economic development. However, the emirate's average resident consumes three times the world average. If the rest of the world followed suit, 4.5 planets would be required to support the demand.

Decoupling population and economic growth from their environmental impact is a priority for Abu Dhabi Emirate. The Government aims to achieve this by pioneering the efficient use of resources, particularly water and energy, through the adoption of more sustainable lifestyles and cleaner technologies, fostered by whole-of-government environmental policies.

2 Introduction

What are Drivers?

Drivers are natural or human influences that directly or indirectly cause change in an ecosystem [1].

A direct driver unequivocally influences ecosystem processes. These include climate change, nutrient pollution, land conversion, over-exploitation and invasive species and diseases.

An indirect driver operates more diffusely by altering one or more direct drivers. They include demographic, economic, socio-political, scientific, technological, cultural and religious factors.

Understanding the factors that cause environmental change provides vital information for policy-making. The most important leverage points for intervention in the interactions between society and environment may not be the pressures themselves but the drivers, as they are the root causes of environmental change [2].

This chapter focuses on those drivers common to several of the environmental themes in this report. Typically, these are anthropogenic, induced by humans through consumption and production activities. They are reviewed together here to avoid repetition in subsequent chapters.

This chapter does not discuss the mechanisms by which drivers interact with specific ecosystems, altering their ability to deliver services. Where relevant, this will be covered in each individual chapter of the report.

Abu Dhabi Emirate's population reached over 2.8 million residents in 2015

2.1 Demographic Drivers

Demographic drivers include population size and its rate of change over time. This is determined by factors including: fertility, mortality and net migration rates; age and gender structure; spatial distribution; and level of education attainment [1].

Population Size and Growth

Abu Dhabi Emirate experienced a rapid increase in population after oil exports began in 1962. In that year, the population was recorded as 28,274 residents. In mid-2015, the population of Abu Dhabi Emirate was approximately 2.8 million people, which is over 14 times greater than in 1975, three times greater than in 1995, and twice as large as in 2005 [3, 4] (see Figure 2.1).

The average annual population growth for Abu Dhabi Emirate in the period 2005 to 2015 was 7.3 % [3]. To put this figure in perspective, in 2010 the global average annual population growth was 1.2 % [5] (0.8 % for countries of very high human development, and 2.4 % for countries of low human development [6]).

Population size and other demographic variables influence the use of food, materials, land, water, energy, transport and a wide range of ecosystem services. A number of studies demonstrate that population size has an impact on consumption and pollution but may be less important than increasing income, culture, technology and public policy, which have a greater influence on what and how much people consume [1].

33 % of the emirate's current population is under 25 years of age

In the case of the Emirate of Abu Dhabi, some of the available evidence points to a strong correlation between population growth and environmental change. For example, the latest greenhouse gas (GHG) inventory shows that total emissions increased by 16.3 % from 2010 to 2012, while the population increased by 15.4 % during the same period.

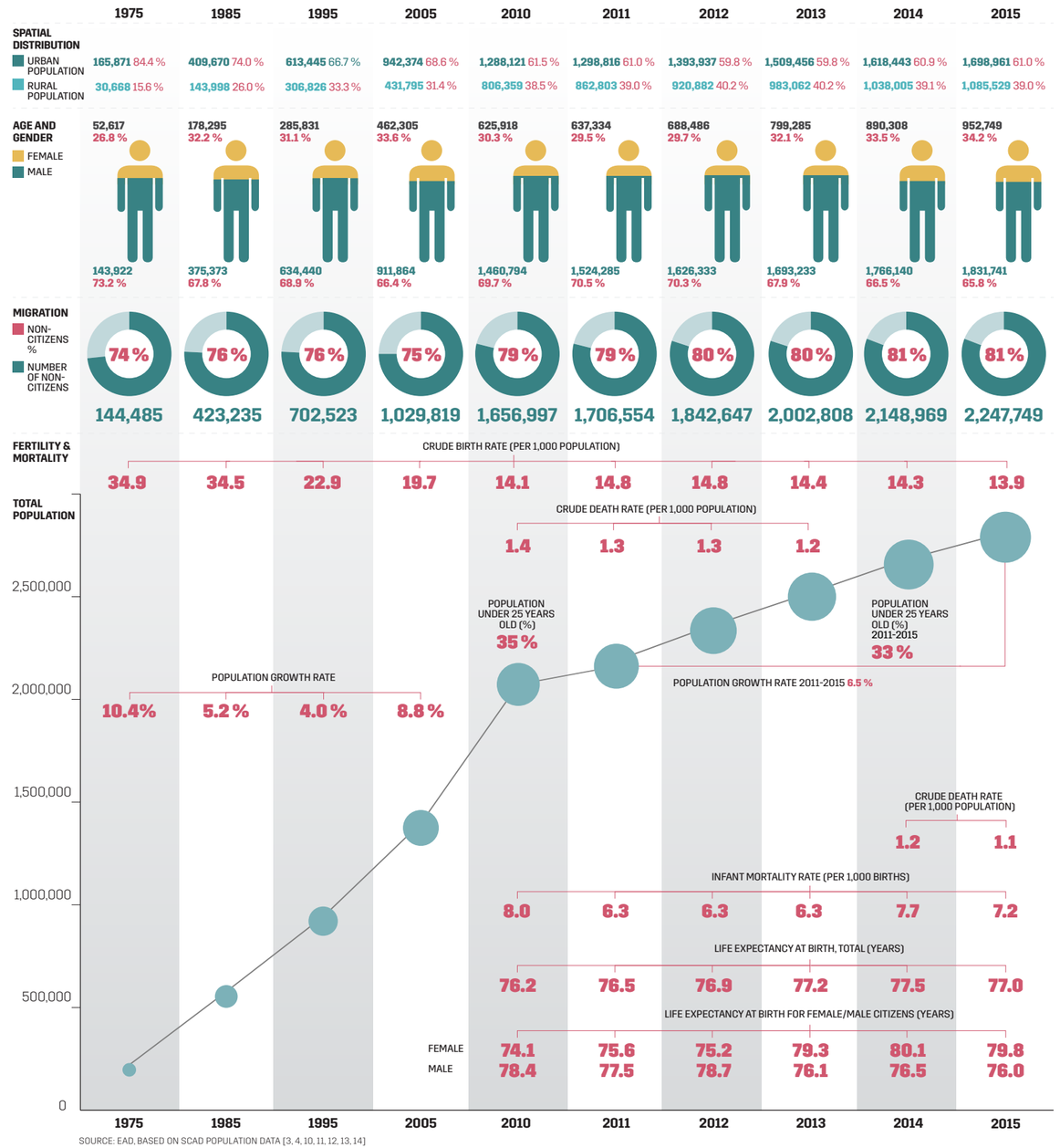
Migration Patterns

The main reason for rapid population growth in Abu Dhabi Emirate has been the influx of expatriate workers required to meet the emirate's development needs. As a result of this influx, the number of non-citizens has tripled since 1995 and doubled since 2005 (see Figure 2.1).

The proportion of migrant workers in the region is considered the third largest in the world, after the European Union and North America [7]. On one hand, this has led to a more cosmopolitan society comprising one of the world's most diverse workforces. On the other hand, it has led to a demographic imbalance: in mid-2015, 2.25 million people (81 % of the Abu Dhabi Emirate population) were non-citizens compared to only 0.53 million Emirati nationals (19 %) [3] (see Figure 2.1).

There is a lack of available research on how this demographic mix drives environmental change in the UAE. The scant evidence available shows that consumption varies greatly by nationality and lifestyle. A considerable number of expatriates are low-income workers who are employed in low-skilled professions (such as construction and domestic help) and live frugally. A large portion of UAE nationals live in larger villas and shabiyat. A demand-side management study conducted by the Government of Abu Dhabi in 2009 found a large discrepancy in water consumption by non-nationals versus UAE nationals. *Per capita*

FIGURE 2.1 Demographic Indicators, Abu Dhabi Emirate (mid-year estimates)



SOURCE: EAD, BASED ON SCAD POPULATION DATA [3, 4, 10, 11, 12, 13, 14]

Increasing consumption adds further pressure to the arid emirate's precious groundwater supplies

TABLE 2.1 Population and Demographics, Abu Dhabi Emirate

Population estimates by region and spatial distribution, mid-year estimate (people)

	1975	1985	1995	2005	2010	2015
ABU DHABI EMIRATE						
TOTAL POPULATION, MID-YEAR ESTIMATE (PEOPLE)	196,539	553,668	920,271	1,374,169	2,094,480	2,784,490
URBAN POPULATION, MID-YEAR ESTIMATE (PEOPLE)	165,871	409,670	613,445	942,374	1,288,121	1,698,961
URBAN POPULATION, MID-YEAR ESTIMATE (%)	84 %	74 %	67 %	69 %	62 %	61 %
RURAL POPULATION, MID-YEAR ESTIMATE (PEOPLE)	30,668	143,998	306,826	431,795	806,359	1,085,529
RURAL POPULATION, MID-YEAR ESTIMATE (%)	16 %	26 %	33 %	31 %	38 %	39 %

SOURCE: EAD BASED ON SCAD POPULATION DATA [3, 4, 10, 11, 12, 13, 14]

consumption by apartment dwellers was comparable to averages in the UK, US and other developed countries. However, for villas, consumption for UAE nationals was 1.8 times that of non-nationals. The considerably greater levels of consumption by villas was likely attributed to outdoor uses (e.g. irrigation, car washing and swimming pools) which, according to data from a Survey of Residential Water by the Regulation and Supervision Bureau (RSB), accounted for 62 % of water use in villas and shabiyat.

Fertility and Mortality

A second factor for rapid population growth in Abu Dhabi Emirate has been the steady increase of the Emirati population. The number of Emirati nationals resident in the emirate has doubled since 2005 and almost quadrupled since 1995.

Among Emirati nationals, there is a considerably higher birth rate than death rate, and the fertility rate among this sector of the population is higher than in most of the developed world. In mid-2015, this was recorded as 13.9 births compared to the rate of most high-income countries, which is estimated to be below 11 births *per* 1,000 of the population [8]. Mortality levels are also low, with 1.1 deaths *per* 1,000 of the population, and infant mortality rates at 7.2 deaths *per* 1,000 live births. The life expectancy for Emirati nationals at birth was 77.0 years, approaching the level of developed countries [3] (see Figure 2.1).

Age and Gender Structure

More than 33 % of the population of Abu Dhabi Emirate is under 25 years of age. This is higher than the GCC average, where 25 % of the population is under 25, rating second highest in the world, after Africa [9].

Studies have shown that young people have a different environmental footprint than older generations. However, there is a lack of available research to understand how these drivers work in a local context. The Abu Dhabi Government expects that those differences will become larger in the future. As more young people become aware of the importance of protecting the environment and are empowered to do so through initiatives such as Sustainable Schools and Sustainable Campus launched by the EAD in 2009 and 2013, the expectation is that the environmental footprint of younger people will decrease with time.

Regarding gender structure, more than 66 % of the emirate's population is male, due to the prevalence of male migrant workers.

Spatial Distribution

More than 60 % of the population of Abu Dhabi Emirate resides in the emirate's urban centres, close to the coast, and Al Ain (see Table 2.1). This is slightly lower than the average for high-income countries, which typically have populations that are 70 to 80 % urban [1].

Studies have shown that household consumption (and therefore environmental impact) differs between rural and urban dwellers. However, there is insufficient research available to understand how these drivers work in a local context.

The phenomena of 'coastalisation' (i.e., the concentration of population and economic activities in coastal spaces) involves the spread of settlements along the coastline. In this instance, much of the development is diffused and therefore very difficult to manage, significantly contributing to loss of essential coastal habitats and vegetation, and exacerbating other issues including pollution and coastal vulnerability.

2.2 Economic Drivers

GDP *per capita* in Abu Dhabi Emirate is one of the highest in the world

Economic drivers include economic growth and its distribution, production and consumption patterns, taxes and subsidies, and trade and capital flows [1].

Economic Growth

Economic growth is the result of higher production and consumption levels and is an important driving force behind the depletion of natural resources and the generation of pollution.

A widely-used indicator of economic growth is Gross Domestic Product (GDP). This is an estimate of the value of all final goods and services produced and traded for money in an economy within a given period.

After oil exports began from Abu Dhabi Emirate in the 1960s, the emirate's GDP increased very rapidly and has continued to grow since then. But GDP *per capita* at constant prices decreased over the same period, presumably due in part to the rapid increase in population [3, 4]. In spite of this decrease, Abu Dhabi Emirate's GDP *per capita* remains one of the highest in the world.

A variety of studies demonstrate that income strongly influences what and how much people consume. For the Emirate of Abu Dhabi, some of the available evidence indicates a strong correlation between economic growth and environmental change. For example, the latest GHG inventory shows that total emissions increased by 16.3 % from 2010 to 2012, while the emirate's total GDP at constant prices increased by 4.8 % in the same period.

Production

The oil sector has been the main contributor to economic growth in the Emirate of Abu Dhabi, with the Government using the significant liquidity generated from oil revenues to follow a gradual economic development and modernisation pathway [7].

More recently, the Government of Abu Dhabi put in place a number of economic policy priorities to diversify the economy into non-oil sectors. These priorities are stated in the Abu Dhabi Economic Vision 2030 [15], which identifies 12 sectors as the engines of future economic growth: Energy – Oil & Gas; Petrochemicals; Metal Processing; Aviation, Aerospace & Defence; Pharmaceuticals, Biotechnology & Life Sciences; Tourism; Healthcare Equipment & Services; Transportation, Trade, & Logistics; Education; Media; Financial Services; and Telecommunication Services.

Therefore, part of the planned economic growth for the emirate is based on the development of heavy, state-owned export-oriented industries, such as metal processing. These industries require abundant and cheap energy to be highly competitive in international markets, driving up GHG emissions. Part of the planned growth is also driven by knowledge-based industries and the services sector (such as tourism). While these industries are dependent on people who consume less electricity than heavy industry, they demand a range of different resources (such as food, water and transport) which also stress the environment.

Consumption

Abu Dhabi Emirate contributes about 60 % of the UAE's GDP [3], and has one of the highest GDPs *per capita* in the world (see Table 2.2). The GDP *per capita* at 2011 purchasing power parity for the UAE was USD 57,045. The same indicator for the first three countries ranked in the Human Development Index were Norway (USD 62,448), Switzerland (USD 54,697) and Australia (USD 42,831) [6].

As *per capita* income grows, the structure of consumption changes, which affects the environment. The share of additional income spent on food declines and the consumption of industrial goods and services rises. The composition of the population's diet changes, with more consumption of fat, meat, fish, fruits and vegetables. Energy and materials intensity (use *per* unit of economic output) tend to decline. Although outpaced by economic output growth, these tend to rise in absolute terms over time [1].

BOX 2.1 The Ecological Footprint Initiative: Measuring a Nation's Consumption Patterns

In 2006, the Living Planet Report, based on 2003 data, ranked the UAE as the country with the highest ecological footprint in the world. Recorded at 11.9 global hectares *per capita*, it was one of the lowest bio-capacities in the world, at 0.8 global hectares *per* person [19]. This indicated that UAE residents were dependent on the resources of other nations to meet their needs. If everyone in the world consumed like the average UAE resident, 4.5 planets would be required to keep up with consumption and CO_2 emissions, which were three times the world average [20].

In 2007, the UAE Government launched the 'Al Basma Al Beeiyah' initiative to better understand the country's ecological footprint and monitor consumption patterns. Through this, the UAE become the third country in the world (after Switzerland and Japan) to conduct an in-depth research of its ecological footprint. The initiative was developed through a partnership between the Ministry of Environment and Water (now the Ministry of Climate Change and Environment (MOCCAE)), Environment Agency – Abu Dhabi (EAD), the Abu Dhabi Global Environmental Data Initiative (AGEDI), the Emirates Wildlife Society in association with WWF (EWS-WWF), and the Global Footprint Network.

Al Basma Al Beeiyah identified the major footprint-driving sectors and found that UAE households are the greatest contributors, accounting for 57 % of the ecological footprint, followed by the business/industry and government sectors, accounting for 30 % and 12 % respectively. The initiative also found that carbon footprint was the largest component, accounting for 80 %. Because of its hot, arid climate, the UAE requires substantial quantities of energy for cooling and for the desalination of seawater for domestic water supplies [21].

TABLE 2.2 Economic Indicators, Abu Dhabi Emirate

INDICATORS	1975	1985	1995	2005	2011	2012	2013	2014	2015
ECONOMIC GROWTH									
GDP AT CURRENT PRICES (MILLION AED)	35,661	67,487	117,196	383,430	846,684	909,721	931,773	960,146	778,501
GDP AT CURRENT PRICES GROWTH RATE (%)	5.4 %	-6.9 %	8.3 %	31.7 %	32.3 %	7.4 %	2.4 %	3.0 %	-18.9 %
GDP AT 2007 CONSTANT PRICES (MILLION AED)	N/A	167,795	315,846	491,664	641,831	672,668	702,941	733,825	770,011
GDP AT 2007 CONSTANT PRICES GROWTH RATE (%)	N/A	-6.4 %	-0.2 %	4.9 %	9.3 %	4.8 %	4.5 %	4.4 %	4.9 %
GDP *PER CAPITA* AT CURRENT PRICES ('000 AED)	181.4	121.9	127.3	279	391.7	393.0	373.8	361.4	279.6
GDP *PER CAPITA* AT CURRENT PRICES GROWTH RATE (%)	-15.8 %	-12.1 %	3.0 %	26.0 %	28.2 %	0.3 %	-4.9 %	-3.3 %	-22.6 %
GDP *PER CAPITA* AT 2007 CONSTANT PRICES ('000 AED)	N/A	303.1	343.2	357.8	296.9	290.6	282	276.2	276.5
GDP *PER CAPITA* AT 2007 CONSTANT PRICES GROWTH RATE (%)	N/A	-11.5	-5.2	0.4	5.9	-2.1	-2.9	-2.0	0.1
PRODUCTION									
OIL SHARE IN GDP AT CURRENT PRICES (%)	76.6 %	49.9 %	42.5 %	55.9 %	57.0 %	56.7 %	54.5 %	50.6 %	35.1 %
OIL SHARE IN GDP AT 2007 CONSTANT PRICES (%)	N/A	50.2 %	65.6 %	59.0 %	52.6 %	52.1 %	51.4 %	49.5 %	49.2 %
CONSUMPTION									
FOOD CONSUMPTION *PER CAPITA* (KG/YEAR)	N/A	N/A	N/A	632.7*	N/A	N/A	N/A	636.7	N/A
ENERGY CONSUMPTION *PER CAPITA* (MILLION BTU/PERSON)	N/A	585	654	633	728	N/A	N/A	N/A	N/A
ENERGY INTENSITY (BTU/ YEAR 2005 USD PPP)	N/A	15,983	23,350	16,684	16,772	N/A	N/A	N/A	N/A
MATERIAL INTENSITY (KG *PER* USD GDP) (UAE-WIDE FIGURE)	N/A	0.8143	0.8731	0.8957	N/A	N/A	N/A	N/A	N/A
ECOLOGICAL FOOTPRINT									
ECOLOGICAL FOOTPRINT (GHA/PERSON)				11.9	8.4*	N/A	N/A	N/A	N/A
TOTAL BIO-CAPACITY (GHA/PERSON)				0.8	0.6*	N/A	N/A	N/A	N/A
ECOLOGICAL RESERVE OR DEFICIT (GHA/PERSON)				-11.1	-7.6*	N/A	N/A	N/A	

SOURCE: [4, 16, 17, 18, 19, 20]
NOTE: *FOOD CONSUMPTION DATA FOR 2005 CORRESPONDS TO 2008. ECOLOGICAL FOOTPRINT DATA FOR 2005 CORRESPONDS TO 2003 AND DATA FOR 2011 CORRESPONDS TO 2010 (SEE BOX 2.1)

2.3 Socio-political, Cultural and Religious Drivers

Socio-political drivers encompass the forces that influence decision-making. They include public participation in decision-making, the role of the state relative to the private sector and levels of education and knowledge [1].

Cultural drivers include the values, beliefs and norms that a group of people share. These condition their perceptions of the world, influence what they consider important and may inspire courses of action that are appropriate or inappropriate [1].

Public Participation in Decision-making

Studies on public participation in environmental decision-making indicate that such involvement leads to more sustainable approaches to managing natural resources. In the Emirate of Abu Dhabi, traditional public participation channels, like majlis, are used without being formalised in the official governance structure.

Education and Knowledge

People with different levels of education tend to vary in their awareness and behaviour towards the environment. Better education typically implies better access to relevant information and is also linked to more eco-friendly consumption and willingness to embrace technological advancements to protect the environment.

Data from the Statistics Centre – Abu Dhabi (SCAD) [3] show major progress on education attainment over time, but also room for improvement. In mid-2014, the percentage of the population of Abu Dhabi Emirate attaining a university or higher certificate was 17 %. This figure is lower than the gross enrolment ratio in tertiary education in high-income countries and in low- and middle-income countries, which was estimated at 73 % and 23 % respectively in 2013 [8].

2014 data from EAD also showed an improvement in the level of environmental awareness of the local population. However there is no data on how this improvement is linked to education levels or how it affects behavioural changes.

Further improving education attainment levels will not be enough to reduce environmental pressures if environmental protection is not placed at the core of the education system. With this in mind, EAD launched the Sustainable Schools Initiative in 2009, with the aim of raising youth awareness on the importance of protecting the environment and empowering them to take action. Following the programme's success, EAD launched the Sustainable Campus Initiative in 2013. Continuing and expanding on these efforts is needed to mainstream environmental protection in the education system. Of the 24 universities accredited by the Ministry of Higher Education and Scientific

TABLE 2.3 Socio-political and Cultural Indicators, Abu Dhabi Emirate

INDICATORS	1975	1985	1995	2005*	2011	2012	2013	2014	2015
EDUCATION ATTAINMENT									
ILLITERACY RATE AMONG TOTAL POPULATION (10 YEAR AND ABOVE) (%)	41.04 %	25.59 %	23.38 %	12.61 %	10.50 %	9.20 %	7.20 %	6.40 %	7.0 %
POPULATION WITH UNIVERSITY OR HIGHER DEGREE (%)	N/A	N/A	N/A	14.2 %	14.1 %	14.2 %	16.8 %	15.7 %	17.9 %
ENVIRONMENTAL AWARENESS									
ENVIRONMENTAL AWARENESS INDEX (%)	N/A	N/A	N/A	49 %	N/A	44 %	60 %	71 %	N/A

SOURCE: [4, 22]
NOTE: *ENVIRONMENTAL AWARENESS DATA FOR 2005 CORRESPONDS TO 2008.

Better education levels are linked to a higher level of eco-friendly consumption

Research, only four offer degrees in environmental sciences, of which only two are located in Abu Dhabi Emirate. These degrees focus on the socio-economic issues related to the environment rather than approaching environmental science from an empirical perspective. As it is critical that decision-making is based on rigorous empirical environmental data, this deficit leaves a gap in training opportunities for the next generation of potential environmental managers.

Culture and Religion

The federal constitution declares that Islam is the official religion of the UAE. In the Qur'an, Muslims are instructed to look after the environment and not to damage or alter what has been created.

The Hadith also ask Muslims to look after the earth because it is Allah's creation and state that it is part of a human's duty to Allah to protect and conserve the environment.

Islamic teachings have a great influence on everyday life in Muslim society. In cooperation with the General Authority for Islamic Affairs and Endowments, EAD has explored how to teach the importance of conservation of natural resources, especially water, using Islamic principles. This became part of the 'Watersavers' campaign, which was launched in 2010 to reduce water usage in Abu Dhabi Emirate. Expanding on this initiative may be an effective way to spread the message of water conservation through mosques and promote the concept of sustainability within the Muslim population.

The influx of foreign workers and their families to the Emirate of Abu Dhabi has led to the creation of one of the most diverse societies in the world. Multiple cultures, values, social norms and religions co-exist alongside Islam, influencing residents' consumption behaviours. Currently, there has been minimal research on how culture and religion may influence environmental change in the local context.

2.4 Scientific and Technological Drivers

The development, diffusion and adoption of scientific knowledge and technologies can have a profound impact on the environment and human wellbeing. The rapid growth of environmental research in the UAE has led to a marked improvement in the quality and availability of environmental data for the emirates. For example, half of all coral reef research ever published in the Gulf region has taken place over the past decade, and the UAE is ranked first for the number of research articles published in comparison with all other Gulf countries [23].

On the one hand, productivity improvements from the application of science and technology accelerate GDP growth, reinforcing economic drivers. On the other, improvements in extractive capabilities due to new technologies can have unintended effects that can lead to the depletion of natural resources. For example, advances in fishing technologies in the emirate have contributed to a significant depletion in marine fish stocks, while advances in water extraction technologies have contributed to the depletion of groundwater resources.

On a more positive note, the application of science to the development of cleaner technologies can contribute to a reduction in the carbon and energy intensity of economic activities. For example, the latest solar-powered desalination technology being tested by Masdar, or the deployment of more efficient cooling systems (as recommended by the Executive Affairs Authority), may help reduce the emirate's carbon footprint.

Scientific knowledge is being applied in the emirate through the use of cleaner technologies, such as solar power

2.5 Public Policy Drivers

Recent transportation policies in Abu Dhabi Emirate aim to reduce vehicle emissions

Domestic policy can have a serious effect on the environment. Population growth can be substantially changed by political decisions affecting fertility, migration flows or urban-rural distribution.

Consumption rates can be influenced by sector-specific subsidies on agriculture, electricity and water or fossil fuels. The speed of scientific research and technological change can be affected through the setting of research priorities and changing levels of funding.

If (as indicated by the Ecological Footprint Initiative) more than 80 % of the UAE environmental footprint is carbon, public policy needs to focus on reducing the amount of energy required for activities such as cooling, the desalination of seawater for water supplies, and for mobility. This is to decouple population and economic growth from their environmental impacts.

In recent years, new policies have been introduced in the electricity and water sectors to curb consumption through a reduction of subsidies and the introduction of incentives to increase end-user efficiency. New policies have also been introduced in the transportation sector to reduce emissions through comprehensive surface master plans, low emission zones and vehicle efficiency standards.

One over-arching policy that will have a significant effect on the environment is the Abu Dhabi Plan. This ambitious, five-year, whole-of-government plan was recently unveiled by the Government of Abu Dhabi, and aims to achieve Abu Dhabi's vision of maintaining a safe and secure society, and building a more sustainable, diversified and globally open economy.

It is still too early to gauge the impact of this set of policies on environmental change in the emirate. For that, it is extremely important for Abu Dhabi Government to continue the systematic evaluation of the effectiveness, efficiency and equity of public policies, in order to publish and utilise this information for improving our capabilities in protecting the environment before any change becomes irreversible.

AIR QUALITY

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KEY MESSAGES

DRIVERS

Changes in air quality in Abu Dhabi Emirate are primarily brought about by population growth with a concomitant increase in demand for resources, as well as transport emissions.

PRESSURES

Emissions from industry and transport, as well as natural dust events, are a main cause of pressure on the quality of air in the emirate.

STATE

Pollutants of major concern in Abu Dhabi Emirate are particulate matter and ozone. Sulphur dioxide levels are within UAE limits in most of the ambient air quality monitoring network, although an increase in concentrations has been observed over the past few years in the Al Dhafra Region. Hydrogen sulphide concentrations are not at harmful levels to the public, but frequent episodes of odour nuisance due to hydrogen sulphide have been recorded. Levels of nitrogen dioxide and carbon monoxide are below the limits set in the UAE air quality standard.

IMPACTS

Air pollutants have a significant impact on human health in the emirate, as well as environmental, social and economic factors.

RESPONSES

Efforts to improve air quality are cross-sectoral, and include monitoring, regulations, enforcement, environmental planning, research and awareness, leading to a healthier environment and better quality of life.

3 Introduction

KEY INDICATOR OF CURRENT STATE: **76 %** **OF TIME WITHIN NATIONAL AIR QUALITY LIMITS IN 2015**

Good air quality is essential for the health and wellbeing of the population in Abu Dhabi Emirate and an intrinsic part of what makes it an attractive place to live and work. Therefore, for sustained growth in the emirate, it is crucial to maintain good quality air standards while pursuing economic development. Air pollution incurs costs associated with low employee productivity, healthcare, reduced agricultural yields, poor visibility that impacts transportation activities, and increased cleanliness and maintenance requirements of infrastructure.

Globally, air pollution is a major public health concern, particularly in urban areas where population density and pollutant concentrations are greatest. According to the UAE's Environmental Burden of Disease Assessment [1], outdoor air pollution is the leading environmental cause of respiratory and cardiovascular diseases and medical visits in the UAE.

Air quality is a complex environmental issue. Air pollution may originate from man-made sources (such as industry and motor vehicles) or from natural sources (such as dust events). Air pollutants can be transported for long distances in the atmosphere, so that pollutants released in one country may contribute to or result in poor air quality elsewhere [2].

Abu Dhabi Emirate is working to improve its air quality within the framework of the UAE Vision 2021 [3] and Abu Dhabi Plan [4]. The leadership has a clear vision to monitor the emirate's air quality and implement the most appropriate policies, regulations and incentives, collaborating with a wide range of public and private stakeholders.

Reducing outdoor air pollution also reduces emissions of carbon dioxide (CO_2) and short-lived climate pollutants, such as black carbon particles and methane, thus contributing to the near- and long-term mitigation of climate change [5].

A framework to improve air quality is included within the Abu Dhabi Plan

3.1 State

The state of ambient air quality across the Emirate of Abu Dhabi is constantly monitored through an extensive network of monitoring stations (see Map 3.1).

Table 3.1 summarises the overall compliance and trend analysis of the main pollutants recorded in the ambient air quality network operated by EAD. The network comprises 20 fixed monitoring stations throughout Abu Dhabi Emirate, and two mobile monitoring units. It monitors up to 17 pollutants and select meteorological parameters on an hourly basis. Detailed information on the concentrations and number of exceedances *per* parameter and station are available through the EAD website (www.ead.ae/Pages/Green%20Business/air-quality.aspx), or directly from the Air Quality website (www.adairquality.ae/).

Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a gaseous pollutant which is mainly emitted from fuel combustion in transportation, electricity production, water desalination and oil and gas processing.

For the most part, SO_2 concentrations are within UAE limits. However, over the last few years, trends indicate a slight increase (see Figure 3.1), related to the increase of SO_2 concentrations registered in the Al Dhafra Region.

Carbon monoxide (CO)

Carbon monoxide (CO) is an atmospheric pollutant generated by internal combustion engines (including vehicles, ships and generators).

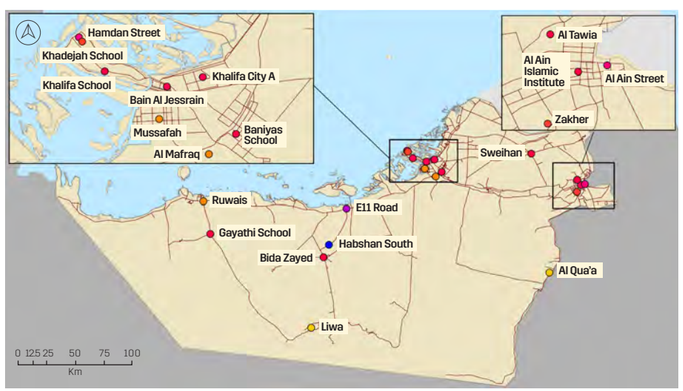
CO in Abu Dhabi Emirate is well within UAE air quality limits, and continuous improvements in engine efficiency have reduced its concentration in the air.

Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) is a gaseous pollutant mainly emitted during fuel combustion. In the past few years, NO_2 concentrations have remained stable and within UAE limits. However, continuous monitoring is required, as the emirate's increase in population and transportation usage may lead to an increase in NO_2 concentrations.

MAP 3.1 EAD Air Quality Monitoring Network

- SUBURBAN BACKGROUND
- SUBURBAN INDUSTRIAL
- RURAL TRAFFIC
- REGIONAL RURAL BACKGROUND
- RURAL INDUSTRIAL
- URBAN BACKGROUND
- URBAN TRAFFIC
- ROAD NETWORK
- EMIRATE OF ABU DHABI



SOURCE: EAD

The emirate's growth in transportation and industrialisation has led to increased levels of air pollutants

Ozone (O_3)

Tropospheric ozone (O_3), also referred to as 'ground-level ozone', is a secondary pollutant, which means it is not directly emitted from man-made or natural sources. It is formed in the atmosphere by photochemical reactions in the presence of sunlight and precursor pollutants, such as the oxides of nitrogen (NO_X) and volatile organic compounds (VOCs).

Tropospheric ozone concentrations are currently above the UAE limits, with an observed gradual increase recorded over the past few years (see Figure 3.1). Due to the complexity of ozone formation, the main drivers of this increase have not yet been scientifically proven and are the subject of on-going investigation. In order to ascertain the main precursors of O_3 in the region, EAD is conducting a scientific project to improve knowledge about O_3 so as to propose policies and regulations to reduce tropospheric ozone.

Particulate Matter (PM_{10})

Particulate matter less than 10 µm in diameter (PM_{10}) is the term for small solid or liquid particles found in the air. Their presence can be due to natural sources, such as sand from the desert, man-made sources, which are mostly combustion engines, or formed in the atmosphere when gaseous pollutants such as SO_2 and NO_X react.

Background levels of PM_{10} are significantly high in Abu Dhabi Emirate due to the arid nature of the region. Concentrations increase when dust events occur, transporting sand and dust into populated areas. The overall trend for PM_{10} levels in the emirate shows stability in the values recorded over the past few

TABLE 3.1 Compliance with the UAE Standards and Trend Analysis *per* Pollutant

	COMPLIANCE WITH UAE LIMITS	TREND (2007-15)
SULPHUR DIOXIDE (SO_2)	↑	↑
CARBON MONOXIDE (CO)	↑	↓
NITROGEN DIOXIDE (NO_2)	↑	=
OZONE (O_3)	↓	↑
PARTICULATE MATTER WITH 10 µm OR LESS IN DIAMETER (PM_{10})	↓	=
HYDROGEN SULPHIDE (H_2S)	N/A	↑

(N/A) = Not Applicable. There are no ambient air quality standards for hydrogen sulphide in UAE.
COMPLIANCE WITH UAE STANDARDS: ↑ Compliant ↓ Non-compliant
TREND: ↑ Increasing ↓ Decreasing = Stable

SOURCE: EAD - AMBIENT AIR QUALITY NETWORK

years. This may be an indication of the significance of the high background levels due to natural sources of PM_{10}.

Particulate matter less than 2.5 µm in diameter ($PM_{2.5}$), also known as 'fine particles', is also a key pollutant that should be measured and analysed. This is due to the potentially adverse effects it can have on human health [6].

EAD has been measuring $PM_{2.5}$ since mid-2012, with the results showing values recorded above World Health Organisation (WHO) guidelines. At present, the UAE has not set standards for $PM_{2.5}$. However, EAD is working on a chemical speciation [7] and source apportionment project in order to determine the main contributors of $PM_{2.5}$ in the emirate. This aims to provide scientific knowledge that supports the development of a national standard and reduces $PM_{2.5}$ concentrations.

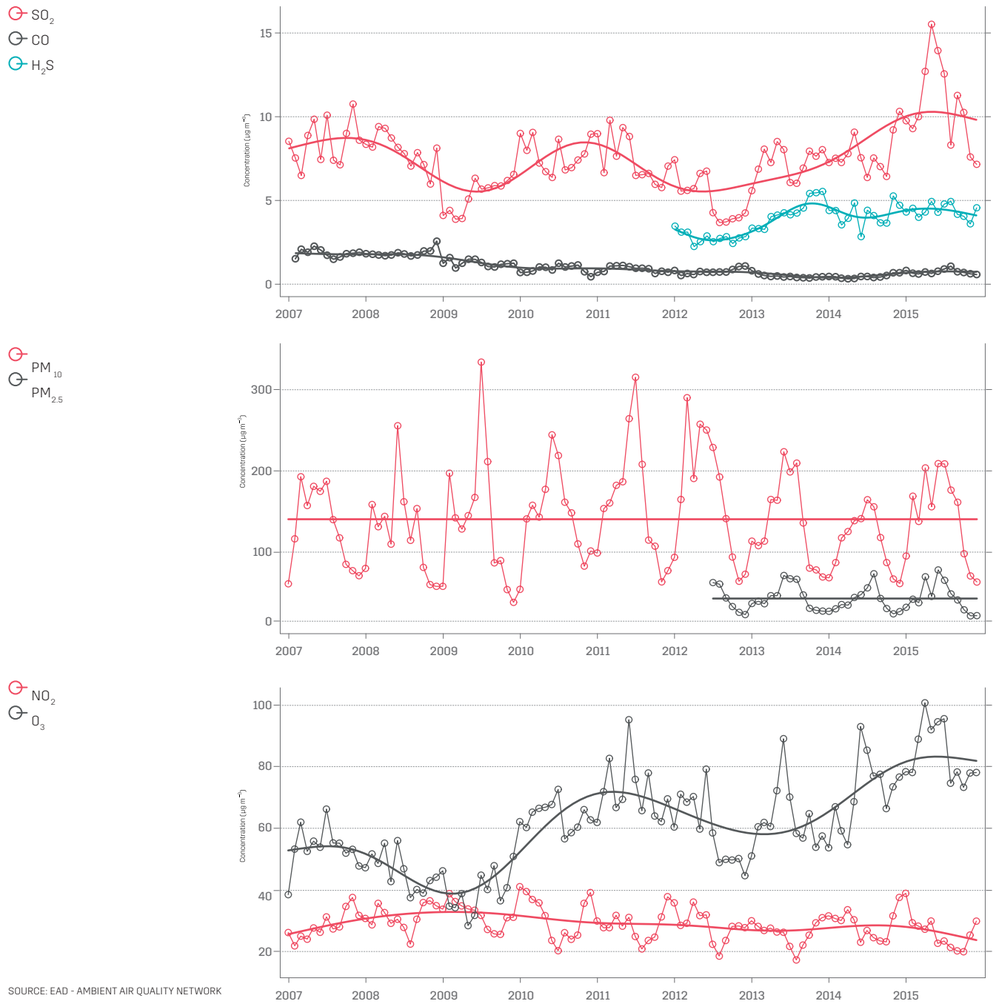
Hydrogen sulphide (H_2S)

Hydrogen sulphide (H_2S) gas has a characteristic odour of rotten eggs and can cause odour nuisance at very low concentrations [8]. Hydrogen sulphide is not considered a 'criteria pollutant' in the UAE; however it is monitored by EAD and is included in this report due to its importance to the population's wellbeing. H_2S concentration measurements in Abu Dhabi Emirate are well within the threshold recommended by WHO. However there has been an increase in H_2S concentrations in certain specific areas, as well as in the number of odour complaints.

The main emission sources of H_2S in the emirate are the illegal dumping of solid waste and sewage, fugitive emissions from sewage distribution systems, wastewater treatment plants, and oil and gas activities.

Background levels of particulate matter are naturally high in Abu Dhabi Emirate due to the arid climate

FIGURE 3.1 Monthly Average Concentration (dots) and Smooth Trend per Pollutant (lines) of the Entire Abu Dhabi Emirate Ambient Air Monitoring Network (concentrations expressed in µg/m3)



SOURCE: EAD - AMBIENT AIR QUALITY NETWORK

3.2 Drivers & Pressures

Significant emissions come from industrial processes and the oil and gas industry

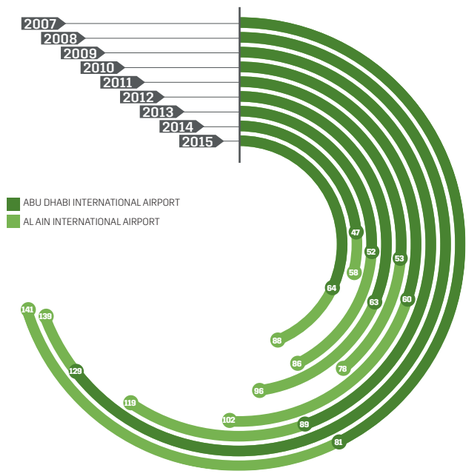
Demographic factors, as described in Chapter 2 – Drivers of Environmental Change, play an important role in the pressure that is put on the environment, and air quality in particular, as a consequence of rapid infrastructure development, demand for water and electricity, transportation and land-use.

A significant amount of emissions in Abu Dhabi Emirate come from point sources, including facilities involved in oil and gas production and processing, electricity production, water desalination and industrial processes. Line sources, such as motor vehicle traffic and marine vessels, are also important contributors to the emirate's total emissions (See Figure 3.4).

Observed trends in SO_2, NO_2, and CO emissions are consistent with increases in electricity production, water desalination, motor vehicles and various industrial fuel combustion activities in Abu Dhabi Emirate. According to ambient air quality monitoring measurements, these pollutants generally remain within national limits. However, where road traffic is a significant contributor, exposure to pollution and impact on the public increases considerably. This is due to the concentration and proximity of these mobile sources to residential areas, commercial areas, schools and public spaces. This phenomenon must be considered and addressed by any abatement programmes.

In Abu Dhabi Emirate, ground-level ozone (O_3) is a big challenge as it frequently exceeds the limits set by the UAE's national ambient air quality standards. Its precursors are emitted from oil and gas activities, some industrial processes, petrol stations and transport, as well as from biogenic sources such as vegetation. The ability of O_3 and its precursors to travel long distances from their sources requires any management programme to include a comprehensive monitoring and management protocol.

FIGURE 3.2 Number of Days with Dust Events Monitored in Abu Dhabi Emirate During the Period 2007 to 2015



SOURCE: NATIONAL CENTER OF METEOROLOGY AND SEISMOLOGY

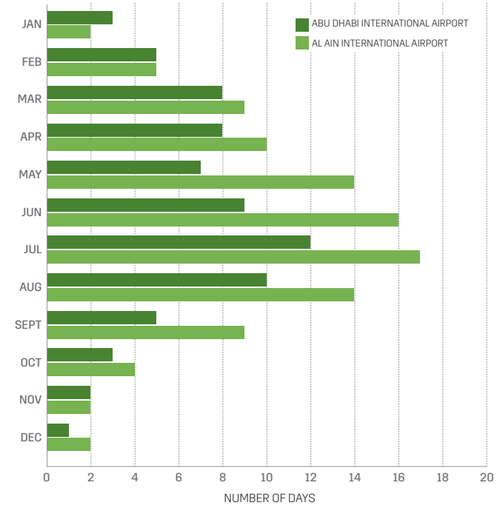
Pollution levels caused by road traffic near residential areas may cause a health impact on the population

Levels of PM_{10} and $PM_{2.5}$ in Abu Dhabi Emirate frequently exceed the national standard limit values for the former and guideline values for the latter. Due to the arid climate and desert environment, Abu Dhabi Emirate experiences regular dust events throughout the year (see Figure 3.2 and Figure 3.3).

Although the emirate experiences high natural background levels of both of these pollutants, anthropogenic sources also contribute a substantial amount. Preliminary scientific studies show that a significant percentage of its precursors is from anthropogenic sources, including road traffic, shipping and industry [9].

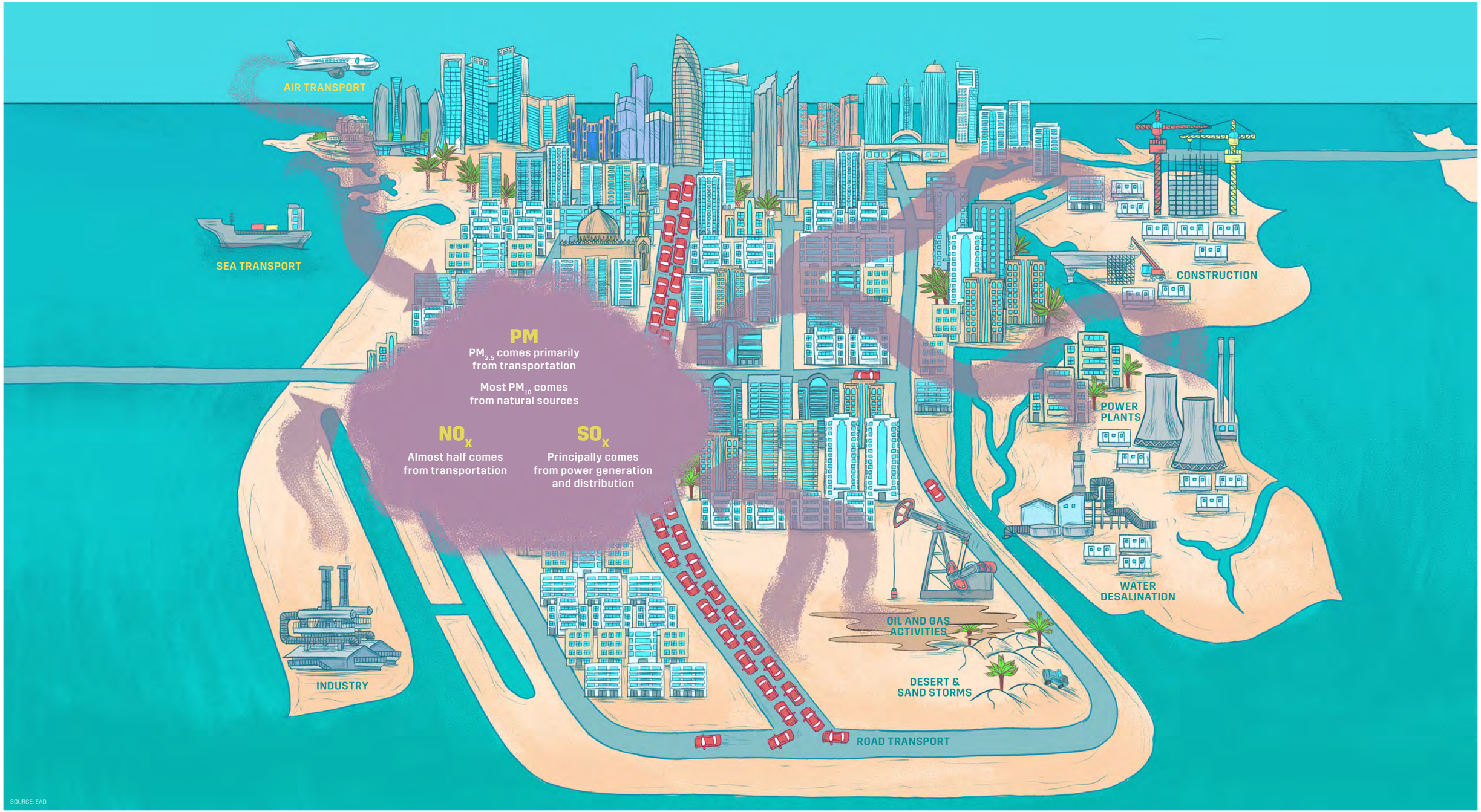
Anthropogenic PM_{10} is mainly caused by infrastructure development and construction activities, as well as by re-suspension on roads due to transport activities.

FIGURE 3.3 Average Number of Days *Per* Month with Dust Events Monitored in Abu Dhabi Emirate During the Period 2007 to 2015



SOURCE: NATIONAL CENTER OF METEOROLOGY AND SEISMOLOGY

FIGURE 3.4 Sources of Air Pollution



SOURCE: EAD

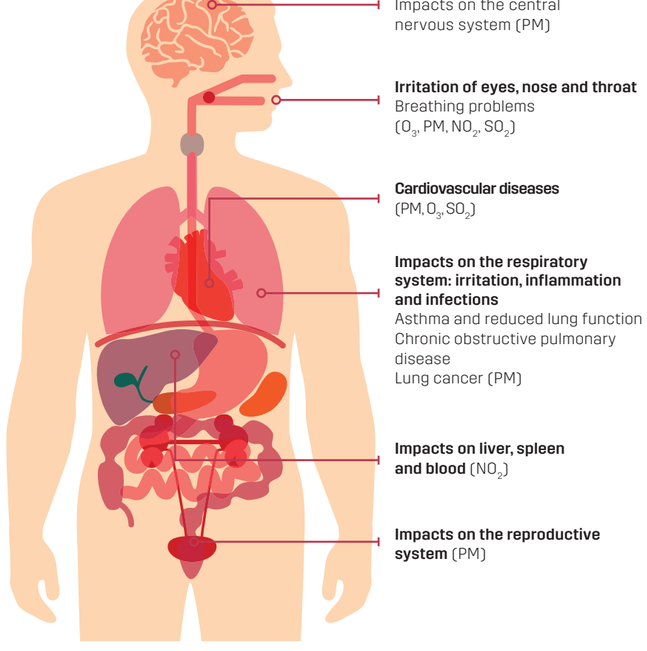
3.3 Impacts

Health Impacts

Air pollutants can potentially have a serious impact on human health. According to the WHO, air pollution is the world's largest single environmental health risk [11]. Globally, 3.7 million deaths are attributable to outdoor air pollution each year.

There have been many epidemiological studies presenting the health impacts of air pollution (see Figure 3.5).

FIGURE 3.5 Health Impacts of Air Pollution



SOURCE: EEA, 2013 [10]

In the UAE, outdoor air pollution is a cause for concern in terms of its potential impact upon human health, as well as its associated healthcare costs. The primary pollutants of concern are PM and ground-level ozone [1]. Health effects from other major pollutants (including NO_2, SO_2, H_2S and CO) are thought to be minimal, because local daily and annual average levels for these pollutants are mostly below UAE national limits.

Environmental Impacts

There are several environmental impacts caused by air pollution [9]:

- Acid deposition, caused by NO_x and SO_x, impacts buildings, water bodies, forests and wildlife.
- Eutrophication of water bodies can stimulate algal blooms and kill fish and plants.
- Tropospheric ozone, which damages vegetation.
- Negative impacts on wildlife caused by air pollutants.
- Short-lived climate pollutants which contribute to climate change.

Little is known about the potential of these impacts on the environment in Abu Dhabi Emirate. Further monitoring and research is required to better understand the local situation.

Social and Economic Impacts

Poor air quality also has a significant impact on socio-economic wellbeing in the Emirate of Abu Dhabi. Reducing air pollution would lead to a reduction in healthcare expenses and working days lost to health-related illnesses, as well as an increase in productivity levels in both public and private companies [12, 13, 14].

3.4 Responses

The Emirate of Abu Dhabi has made efforts to improve ambient air quality and develop direct and strategic responses.

The Removal of Fuel Subsidies

To date, the UAE has taken important steps towards reducing fuel subsidies and deploying cleaner diesel to the domestic market. Further enhancing vehicle fuel efficiency and vehicle emission standards will do much to benefit air quality by reducing emissions of CO, NO_x and SO_x.

Conversion of Government Fleet to Compressed Natural Gas (CNG)

In 2010, Abu Dhabi Executive Council adopted a decision to shift 25 % of vehicles in Government fleets to Compressed Natural Gas (CNG) by 2012. CNG has lower carbon content than diesel or gasoline.

Introduction of Ultra-Low Sulphur Diesel (ULSD)

The promotion of specific fuels must consider local conditions and lifecycle emissions levels. In July 2014, the UAE introduced ultra-low sulphur diesel, reducing sulphur content from 500 ppm to 10 ppm [15]. This not only reduced sulphur emissions from diesel vehicles, but also allows for the introduction of advanced vehicle and emission control technologies that can further reduce PM and NO_x vehicle emissions.

Cleaner vehicle technology is being introduced to municipal fleets to combat air pollution

Promotion of Clean Vehicle Technologies

The Department of Transport (DOT) supports the growth of cleaner energy vehicles within its bus fleets. In 2015, 88 % of buses achieved Euro 4 standards, a European standard signifying the efficient use of diesel fuel. DOT also studied the integration of electric buses into its bus fleet.

Air Quality Monitoring Station Network

Given the rapid changes taking place in the Emirate of Abu Dhabi, from 2012 EAD expanded its network of air quality monitoring stations, adding 10 more across the emirate. Today, the EAD network (see Map 3.1) comprises 20 fixed air monitoring stations and two mobile stations, ensuring the continuous measurement of air quality across the emirate. The main objective is to provide accurate information and data on air quality in the emirate. This enables EAD and other concerned authorities to identify the drivers, pressures and state of the air quality, as well as to monitor the impacts of targeted management and policy responses.

Ambient Air Quality Electronic Linking (E-linking)

Ambient air quality is monitored through different regulatory authorities in Abu Dhabi Emirate. In 2014, EAD successfully linked several air quality monitoring networks in the emirate: the Abu Dhabi Water and Electricity Authority (ADWEA) and Higher Corporation for Specialized Economic Zones (ZonesCorp). With the support of the UAE Ministry of Climate Change and Environment (MOCCAE) to create a UAE-wide network, the National Center of Meteorology and Seismology (NCMS), and the Dubai Municipality networks were also linked.

The E-linked network provides more efficient and far wider coverage across Abu Dhabi Emirate and the UAE. In doing so, it provides a more holistic understanding of the quality of air across the emirates.

The state of ambient air quality in Abu Dhabi Emirate is continuously recorded through a network of monitoring stations

Compliance with Air Quality Standards and Regulations

Monitoring and reporting requirements are specified in environmental permits issued by EAD. They require owners and operators of certain facilities emitting air pollutants to regularly monitor ambient air quality in the vicinity of their facilities and to analyse their air pollutant emissions.

To assist both inspectors and regulated entities, EAD has developed standardised permit conditions for industrial and commercial facilities. The agency has also developed the Inspection and Compliance Tool (ICT), which includes general and sector-specific inspection questions to broaden the scope of environmental inspections and ensure consistency. In order to improve the environmental performance of targeted industrial sectors, EAD launched the Eltezam Environmental Campaign. Campaigns for the ready-mix concrete and fibre-glass sectors have already been successfully completed.

Research-based Air Quality Studies

EAD has initiated and executed a number of activities that have generated new knowledge about air quality. These include:

- $PM_{2.5}$ chemical speciation, source identification and apportionment;
- Ozone precursor monitoring, with the aim of collecting data to gain insight into anthropogenic and natural sources, as well as to understand the processes influencing ozone levels in Abu Dhabi Emirate.
- Mercury Emission Inventory and Emission Scenarios for Abu Dhabi, with the aim of providing emirate-wide estimates of natural and anthropogenic mercury emissions.
- The Abu Dhabi Air Emission Inventory, which compiles data and provides information about the air pollutants released to the atmosphere from different sources.

Energy and Water Efficiency Building Practices

An initiative developed by the Department of Urban Planning and Municipalities (DUPM), Estidama is an effective programme that incentivises the use of energy- and water-efficient construction materials and systems in new buildings. Such measures contribute to lowering the demand for resources, in turn reducing the need for additional power plants that would otherwise be sending emissions to air.

Industry

Abu Dhabi Emirate is working on a number of programmes to reduce the impacts of its industries on air quality.

EAD is developing sector-specific emission limits and promoting the connection of continuous emissions data from the major industries' stacks to the agency in real time. A pilot project has been successfully completed with Umm Al Nar Power Plant, and more stacks will be connected in the near future.

It is important to highlight the great efforts made by many industries in the emirate to use the best available technologies, as well as their plans to continuously improve the efficiency of processes and reduce air pollution.

Transport

The Capital Surface Transport Master Plan, developed by DOT, provides the framework for an accessible and equitable transport system. It aims to encourage behavioural change in society and reduce vehicle-induced emissions.

Another key initiative is the Abu Dhabi Low Emission Vehicles (LEV) Strategy, which will promote the introduction of the best low emission technologies into the private and public sectors.

However, existing inspection and maintenance protocols will have to be reviewed and improved to support the reduction of air pollution.

Research

More investigation is needed to further understand the role of poor air quality on the population's health, and to enhance the mechanisms that reduce air pollution in the emirate. Abu Dhabi Emirate is leading this research with a large number of institutions investigating themes such as $PM_{2.5}$ speciation, ozone precursors, forecasting, and studying the relation between dust events and public health. This research is an important precursor to the development of regionally relevant air quality standards for parameters such as $PM_{2.5}$ where standards currently do not exist.

Research and investigation is an ongoing process continuously supported by Abu Dhabi Government. Furthermore, collaborative engagement between EAD, Health Authority – Abu Dhabi (HAAD), academia and the private sector is critical in improving scientific knowledge about air quality and the link between air pollution and health impacts, as well as providing the best tools and mechanisms to improve the air we breathe.

Awareness Campaigns and Educational Activities

Public acceptance and participation is an essential element for the successful implementation of air quality improvement programmes. Currently, there is little awareness among Abu Dhabi Emirate's general population of air pollution problems. EAD has implemented targeted public awareness campaigns and educational activities, such as the annual Enviro-spellathon, the annual Environment Competition, the Sustainable Schools Initiative and Sustainable Campus Initiative.

Improving the information available to the general public and raising awareness levels in relation to air quality is essential for changing the behaviour of the population and empowering the community to take action for cleaner air.

3.5 Outlook

Looking Ahead

UAE Vision 2021 focuses on improving the quality of air, preserving water resources, increasing the contribution of clean energy and implementing green growth plans [3]. It has set a target of 90 % of days to comply with the national standards for air quality.

Changing Course

A lot of effort has been made to achieve 2021 targets in Abu Dhabi Emirate, and many more measures will be implemented over the following years. This includes: a cross-sectoral approach to improve air quality in the emirate using the best technologies available; implementing the most suitable policies for regional conditions; extensive scientific investigation; and close cooperation between government entities and the private sector.

The national strategy to limit GHG emissions and mitigate climate change will also improve air quality in the emirate. This includes measures to increase the production of energy using renewable sources and increased efficiency in industries and the oil and gas sector. Additionally, Abu Dhabi Government is working on further actions that target the improvement of air quality in the emirate.

Provided all of the planned strategies and programmes continue to be implemented and advances in technology continue, it is anticipated that Abu Dhabi Emirate can continue to grow its population and economy while simultaneously minimising anthropogenic impacts on air quality.

National air quality targets aim to continually improve air quality in the emirate

SOIL

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KEY MESSAGES

DRIVERS

Land degradation in Abu Dhabi Emirate is driven by a number of natural and anthropogenic factors, including wind erosion, salinisation, waterlogging, vegetation loss, expansion of built-up areas, excavation and landfilling.

PRESSURES

The emirate's natural soil salinity, soil erosion, shallow hardpans and low soil fertility limit soil and land development. In addition, there are anthropogenic pressures such as over-grazing and inappropriate irrigation.

STATE

85 % of land in Abu Dhabi Emirate is naturally degraded [1]. There is no available information on the state of soils affected by anthropogenic degradation factors.

IMPACTS

Around 8,000 farms in Abu Dhabi Emirate are abandoned or nearly abandoned because of the impact of salinisation on both soil and water resources.

RESPONSES

EAD has prioritised land and soil to ensure sustainable and integrated approaches to their protection. The Agency's soil contamination guidelines for Abu Dhabi Emirate ensure that sites affected by contaminants are appropriately identified, assessed and, if necessary, remediated or contained to make them safer for human use. Abu Dhabi Quality and Conformity Council (QCC) is conducting a programme to check the competency of local laboratories and build their capacities to bridge gaps and achieve local and international accreditation.

Over a three-year period, EAD is conducting the Soil Salinity Inventory Project to enhance its soil database, in order to provide decision-makers with up-to-date and accurate data to help sustain the emirate's agricultural and food sector. Annual monitoring programmes are being developed by EAD to survey the quality of soil in industrial areas and residential land areas. The Agency has also established a soil archiving facility to meet international standards and provide vital information about changes in soil quality over time.

4 Introduction

KEY INDICATOR OF CURRENT STATE: DATA ON SUITABILITY OF LAND FOR THEIR CURRENT LAND USES WILL BE AVAILABLE IN 2020

What is Soil?

Soil is a non-renewable resource composed of mineral and organic material. It provides sustenance for a large part of terrestrial life, and is the living part and one of the main building blocks of land that comprises soils, rivers and vegetation [2].

Soils deliver ecosystem services that enable life on Earth and perform the following functions [3, 4]:

- Climate regulation
- Nutrient cycling
- Habitat for organisms
- Flood regulation
- Water regeneration and storage
- Source of pharmaceutical and genetic resources
- Foundation for human infrastructure
- Provision of construction material
- Provision of food, fibre and fuel
- Carbon sequestration
- Water purification and soil contaminant reduction
- Culture and heritage

Soil is a living part of the ecosystem in Abu Dhabi Emirate

Soil degradation, which reduces its ability to fulfil its ecosystem services, is the main threat to soils in the UAE [5].

The Global Policy Framework for Soil

A number of recent international initiatives advocate a greater focus on soils in policy development. In 2011, the United Nations Food and Agriculture Organization (FAO) launched the Global Soil Partnership (GSP) in conjunction with the European Commission (EC), 'to provide support and facilitate joint efforts towards sustainable management of soil resources for food security and climate change adaptation and mitigation' [6].

The World Soil Charter has recognised the need to act more forcefully at all levels in order to resolve alarming trends and to maintain the healthy soils required for feeding a growing population [7].

In 2002, the International Union of Soil Sciences (IUSS) made a resolution proposing December 5th as 'World Soil Day', celebrating the importance of soil as a critical component of the natural system and a vital factor for human wellbeing. The FAO-GSP has organised events to mark this day since 2012.

The inaugural Global Soil Week took place in Berlin, Germany, during November 2012, a partnership between the the FAO, EC, United Nations Convention to Combat Desertification, United Nations Environment Programme (UNEP) and Global Soil Forum, which is based at the Institute for Advanced Sustainability Studies (IASS) in Germany. It emphasised the important role of soil in sustainable development and developed an agenda to improve the sustainable management of soils [8]. Target 15.3 of the Sustainable Development Goals (SDGs) sets out a new global ambition to achieve a land-degradation neutral world by 2030.

The UAE recognised environmental problems related to soil by signing and ratifying international environmental agreements including: United Nations Convention to Combat Desertification (1998); Rotterdam Convention on Hazardous Pesticides and Hazardous Chemicals in International Trade; Stockholm Convention on Persistent Organic Pollutants; United Nations Framework Convention on Climate Change and the Kyoto Protocol; and Minamata Convention on Mercury.

Since 1996, the UAE has been an official party to the United Nations Framework Convention on Climate Change, the main framework for intergovernmental efforts to tackle climate change. In 2016, the UAE joined over 170 countries in signing the Paris Agreement, the most significant climate meeting over the last decade that concluded in a new global deal to govern climate action from 2020 onwards. Before Paris, the UAE supported the Lima-Paris Action Agenda declaration. One of the initiatives introduced was the '4 *per* 1,000' project (see Box 4.1), which focused on carbon sequestration through the adoption of appropriate agricultural practices.

BOX 4.1 4/1000 Initiative

The '4/1000 Initiative: Soils for Food Security and Climate' aims to ensure agriculture plays its part in combatting climate change. A 4/1000 annual growth rate of the soil carbon stock intends to show that even a small increase in soil carbon stock is crucial to improve soil fertility and agricultural production and to contribute to achieving the long-term objective of limiting the temperature increase to +1.5/2˚C.

Changes in soil carbon over time become an overall indicator of the natural capital of the soil. The key mechanism in improving and maintaining the functionality of the soil and its ability to support ecosystem service delivery is increasing and managing soil carbon and the biota that transform it. Therefore, change in soil organic carbon (soil carbon) is a significant universal indicator.

Better management of soil carbon is one of the key issues considered not only a part of the soil agenda but also of climate change. UNEP identified this as one of two critical emerging issues for the global environment in its 2012 Yearbook [9].

The Local Policy Framework for Soil

The UAE has established a legal framework that considers the protection of land and soil. Federal Law No. (24) of 1999 for Protection and Development of the Environment included 101 articles, a number of which were linked to soil:

- All of Chapter 3, including six articles, was dedicated to soil protection.
- Article 42 dealt with consideration of environmental standards for planning land utilisation.
- Article 43 prohibited damaging, disturbing or polluting of the soil.
- Article 44 focused on enhancing reserves of the desert, protecting biological diversity and increasing green areas.
- Articles 45, 46 and 47 focused on the management, monitoring and disposal of chemicals (particularly pesticides and fertilisers) that might have impacts on the soil.

4.1 State

The 2009 Soil Survey of Abu Dhabi Emirate (see Soil Survey Project) provides a comprehensive picture of the soils on non-developed land across the emirate (see Map 4.1). It excluded agricultural, industrial and residential land.

Soil Degradation

Soil degradation refers to a change in the natural status of soil health, meaning it is unable to provide its ecosystem services. Land degradation is wider in scope, covering all negative changes in the capacity of the ecosystem to provide land-related biological services, as well as social and economic services [10]. The term 'desertification' is often used to refer to land degradation in dry land areas, and/or the irreversible change of land state. Based on its cause, land degradation is divided into two types: natural and anthropogenic.

Natural Land Degradation

Around 85 % (5.72 million ha.) of land in Abu Dhabi Emirate is naturally degraded (the soil interpretation for 'Land Degradation' evaluates the factors that imply the presence of a soil condition that may be limiting to plant growth) [1]. Table 4.1 shows the different percentages of land in Abu Dhabi Emirate in respect to degradation [1].

The categorisation of degraded land presented in this report has been developed specifically for the environment of Abu Dhabi Emirate. The evaluation accounts for long-term natural factors that have led to the land being in a relatively degraded state.

Map 4.2 displays the extent and distribution of degraded soil areas. Areas along the coast and at Sabkhat Matti are considered degraded due to high salinity. Many inland sabkha, such as those in Liwa, are also degraded by salt. Deflation plains elsewhere

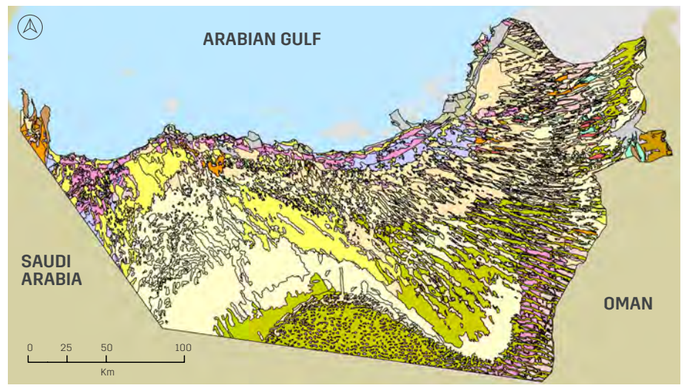
TABLE 4.1 Degraded Land Within Abu Dhabi Emirate

DEGRADATION CATEGORY (RISK LEVEL)	AREA (HA)	PERCENTAGE (%) FROM SURVEY AREA OF 5.72 M HA
HIGH	1,296,000	22.66
MODERATE	4,000	0.06
SLIGHT	4,423,000	77.33

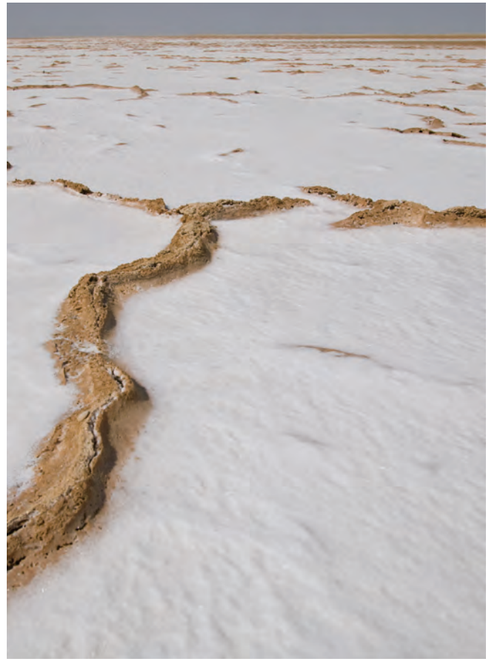
SOURCE: EAD, 2009 [1]

MAP 4.1 Soil Map of Abu Dhabi Showing the Nine Soil Great Groups

- HAPLOCALCIDS
- PETROCALCIDS
- CALCIGYPSIDS
- HAPLOGYPSIDS
- PETROGYPSIDS
- AQUISALIDS
- HAPLOSALIDS
- TORRIORTHENTS
- TORRIORTHENTS - LOW RELIEF (<3M)
- TORRIORTHENTS - LOW- MEDIUM RELIEF (3-<9M)
- TORRIORTHENTS - MEDIUM-HIGH RELIEF (9-<30M)
- TORRIORTHENTS - HIGH RELIEF (>=30M)
- ROCK OUTCROPS
- MISCELLANEOUS UNITS
- OTHERS



SOURCE: EAD, 2009 [1]



Salt degradation is a key area of concern for the emirate's soils

are typically degraded by shallow depth to hardpan or bedrock. The greater part of the emirate, where sandy soils and dune systems occur and erosion by wind is a current hazard, is evaluated as having a slight degradation risk [1].

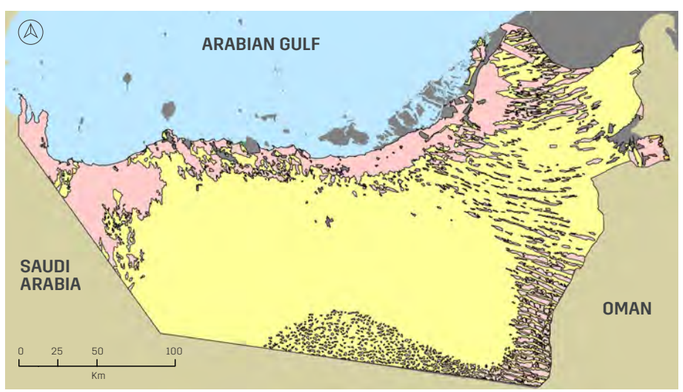
Anthropogenic Land Degradation

The Soil Survey of Abu Dhabi Emirate excluded land degradation caused by human factors, such as contamination from saline irrigated water, fertilisers, pesticides and oil. These factors are found in land that is already used for agricultural, industrial and residential purposes. These areas were not surveyed because the main objective of the survey was to study land suitability for future agricultural expansion in the emirate.

Land degradation caused by the accumulation of contaminants is concentrated in either oil-producing or heavily populated countries. In agricultural soils, contamination is generally restricted to irrigated farming systems [5]. There is no available data on soil contamination in the emirate. However, Abu Dhabi Food Control Authority (ADFCA) has stated that they will be studying soil contamination in Abu Dhabi farms. Salinisation of soil due to irrigation with saline groundwater is a significant situation for many farms in Abu Dhabi Emirate. This situation becomes more complicated when associated with water-logging problems and an increase of $CaCO_3$ [5]. Around 90 % of agricultural farms in Al Ain are affected by increased salinity levels [11].

MAP 4.2 Land Degradation Distribution within Abu Dhabi Emirate

- SLIGHT DEGRADATION
- MODERATE DEGRADATION
- HIGH DEGRADATION
- NOT MAPPED



NOTE: SLIGHT DEGRADATION (YELLOW), MODERATE DEGRADATION (ORANGE), AND HIGH DEGRADATION (PINK).
SOURCE: EAD, 2009 [1]

4.2 Drivers & Pressures

Abu Dhabi Emirate's harsh environmental conditions (including high temperatures, high evaporation rates, limited irregular rainfall, and the fragile structure and low natural fertility of soil) are natural drivers of land degradation. In addition, there are anthropogenic drivers, mainly represented by urban expansion, poor management, inappropriate agricultural practices, over-grazing and dumping of waste.

The specific pressures or threats on soil causing soil and land degradation are also divided into natural and anthropogenic categories.

Wind Erosion

In the UAE, the area of degraded soil caused by wind erosion is 1.1 million ha. [12], and it is the major cause of irreversible land degradation in Abu Dhabi Emirate [13]. Although it is a current natural hazard, wind erosion was evaluated as having a slight degradation risk compared to land degradation by other natural factors such as salinisation in coastal areas and inland sabkhas [1]. However, considering the large area covered with sandy soil in the emirate, wind erosion is a widespread pressure on the environment.

Abu Dhabi Government has made a concerted effort to establish the emirate's forests, which have partially managed the land degradation caused by wind erosion. Forests reduce and stop sand creeping caused by wind erosion, reducing its impact on natural vegetation, reduce air pollution from dust, and protect infrastructure and road safety.

Transformation of rocks due to wind erosion

Salinisation

Salinisation describes the process of increasing the salt content in the soil. This is detrimental to plant growth, damages infrastructure and reduces water quality. It is a widespread problem in the UAE and wider NENA region. However, salinisation varies with climate, agricultural activities and land management policies.

There are natural and anthropogenic causes of salinity in Abu Dhabi Emirate. Seawater and the accession of salt in marine sediments is a natural cause of salinisation. It is the main degradation process in the coastal area of Abu Dhabi Emirate (see Figure 4.3) with salinity of more than 200 dS m-1 [14]. Anthropogenic causes for salinity in Abu Dhabi include:

1) Continuous irrigation over long periods, lowering the water table and allowing for intrusion of seawater;
2) The use of brackish and saline groundwater for irrigation; and
3) Poor on-farm water management and cultural practices in irrigated agriculture.

Over-grazing has caused a loss of vegetation cover

Waterlogging

Waterlogging has become a serious problem for agricultural farms in Abu Dhabi Emirate. This is due to the poor drainage of water caused by the existence of naturally limiting hardpan, an excessive amount of irrigation water and seawater intrusion. Currently, the most affected areas in Abu Dhabi Emirate are Al Ajban, Al Samha, Al Rahba, and Al Bahia [15].

Compacting, Excavation and Landfilling

Compacting, sealing and crusting of soil in Abu Dhabi Emirate are often due to land filling and levelling for infrastructure development. A local study in 2009 found that compaction increased soil bulk density by 44 % and water infiltration dropped by 81 % [5]. Also, the emirate's large-scale excavation activities for construction materials cause notable land degradation, exacerbated by increased development.

Vegetation Loss

The UAE Ministry of Environment and Water's National Strategy to Combat Desertification Report in 2014 reported that the changes in vegetation cover in the period 1999 to 2007 as an indicator for land degradation contributed to around 61.46 % from the country area, at varying levels of degradation. This percentage increased to 95.85 % between 1999 and 2009, due to human activities in agricultural expansion and groundwater depletion [16]. In Abu Dhabi Emirate, the natural vegetation is dominated by few plant species which have sparse distribution in the desert. These species are affected by overgrazing as well as harsh climatic conditions [11].

Natural soil salinity affects over 39 % of Abu Dhabi Emirate's soils

4.3 Impacts

Loose particles from eroded soil can affect the emirate's infrastructure

Soil and land degradation affect the ecosystem function as well as the production of goods and services which benefit humanity. It is important to understand how soil responds to natural and anthropogenic pressures by identifying its ecological, economic and social impacts.

Ecological Impacts

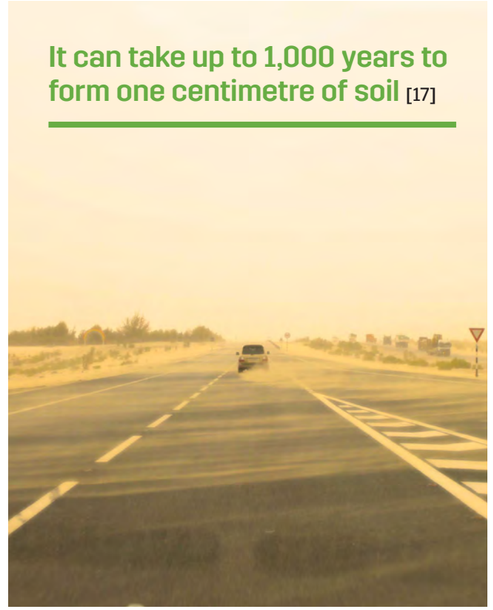
Soil erosion causes the top layer of soil to be removed, losing its essential nutrients and disturbing its structure so it offers little or no support to plant growth. Plants may also be affected by having their roots exposed or buried and blasted by air-borne sand. Soil eroded by strong winds can cause dust events in the atmosphere for a considerable period of time. These impacts mainly happen in open desert, where sandy soils are vulnerable to wind erosion. Over-grazing is another impact, which not only reduces plants' biodiversity, but also exposes soil to erosion and degradation.

The pressures of salinisation and waterlogging on soil are mainly found in agricultural areas. Waterlogging and irrigation with saline water causes a build-up of salt in the soil which increases with time due to the absence of proper leaching. This alters the soil's physical and chemical properties. It also prevents plants from absorbing enough water and suffocates their roots, affecting growth, yield production and survival.

Economic Impacts

Natural and anthropogenic land degradation in Abu Dhabi Emirate affects local production of crops. Around 8,000 farms in Abu Dhabi have been or are nearly abandoned by their owners, mainly because of the impacts of salinisation on both soil and water on their farms, resulting in them becoming unproductive. It will require a considerable budget to rehabilitate lost farms, but it is essential for future food security and will decrease the emirate's percentage of imported food. The Soil Survey of Abu Dhabi Emirate revealed that only 5.44 % of the surveyed area (5,723,000 ha.)

It can take up to 1,000 years to form one centimetre of soil [17]



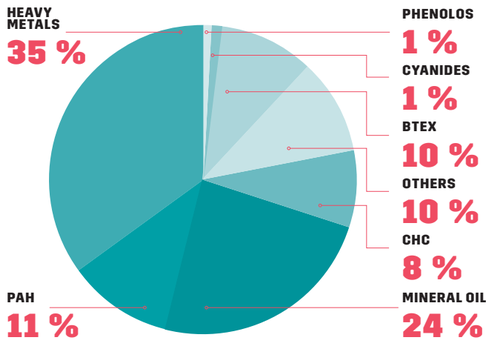
in the emirate is highly to moderately suitable for irrigated agriculture [1].

Eroded soil affects adjacent infrastructure and covers some roads, requiring continuous maintenance. It also affects the efficiency of irrigation systems which become blocked by sand particles.

Health Impacts

Soil contaminants, such as heavy metals and persistent organic chemicals, may be responsible for a range of effects on human health, including cancers (due to arsenic, asbestos and dioxins), neurological damage and lower IQ (from lead and arsenic), kidney disease (from lead, mercury and cadmium), and skeletal and bone diseases (caused by lead, fluoride and cadmium) [18]. Human activities, such as mining, smelting, industry, agriculture and burning fossil fuels,

FIGURE 4.1 Most Frequently Occurring Contaminants in Soil
(EUROPEAN CASE STUDY)



SOURCE: EIONET WORKSHOP ON SOIL [19]

introduce heavy metals (including cadmium, arsenic and mercury) into the emirate's soils.

The use of agricultural pesticides can also lead to soil contamination. Historically, many of these have been persistent in the environment (e.g. dieldrin) and can be taken up by some vegetables and passed on to humans through the food chain.

Generally, people are exposed to contaminants in soil through ingestion (eating or drinking), dermal exposure (skin contact) or inhalation (breathing). They may accidentally ingest small amounts of soil as part of their normal activities, such as yard work, gardening or playing. Young children in particular are thought to be at highest risk from contaminated soils (e.g. children absorb lead through their digestive system five times more efficiently than adults). Both children and adults may also ingest soil while indoors if it is transported into buildings on shoes, clothing or pets. Some contaminants, including many pesticides, are able to enter the body by passing through the skin. Airborne contaminated soil particles (such as wind-blown dust), or contaminants which vaporise from the soil, may be inhaled.

People can also can be exposed to contaminants in soil particles that stick to edible parts of garden produce or are taken up into garden plants from the soil. Animals raised for food may also take in contaminants from soil, with the human population exposed to these contaminants when they eat animal products such as meat, eggs and milk. Drinking water may contain contaminants that were directly discharged into the water source, entered the surface water through run-off, or had leached from the soil into groundwater. In some situations, a contaminant may vaporise from the underlying groundwater and become part of the air that people breathe.

At the present time, there is insufficient information to assess the burden of disease in Abu Dhabi Emirate due to soil contamination. Therefore, steps have been taken to bridge this knowledge gap, starting with the development of the Soil Contamination Guidelines, which consider ways to protect human health and wellbeing.

Impacts of soil quality on human health and wellbeing are being investigated

4.4 Responses

EAD collaborated with Abu Dhabi Quality and Conformity Council to provide a lab which meets international standards of accreditation

Soil Degradation Mitigation

Strategic Reorganisation

Abu Dhabi Government has transformed the way it approaches environmental conservation, optimising sustainability to preserve and protect the emirate's natural heritage. This includes a comprehensive programme, coordinated by EAD, to protect biodiversity and soil quality in the emirate through improved knowledge and awareness-building, and to investigate the potential for rehabilitating degraded areas.

In 2016, EAD promoted land and soil to a priority to ensure sustainable and integrated approaches to their protection. With strategic objectives that need to be fulfilled over a five-year period, these include: strengthening policy and planning framework around soil quality; effectively influencing key stakeholder decisions; improving and enforcing the regulatory framework for soil quality; and ensuring land contamination management and restoration.

Soil Contamination Guideline

In 2016, EAD developed the Soil Contamination Guidelines for Abu Dhabi Emirate. The guidelines' objective is to ensure that sites affected by contaminants are appropriately identified, assessed and, if necessary, remediated or the contaminants contained to make the site safe for human use. The standard provides values for soil screening to assess whether there is a potential risk to human health posed by contamination at the site as well as for clean-up levels to guide remediation. Guideline values have been defined for different land uses including residential, industrial, and agricultural. These will be transformed into easily enforceable local regulations.

Soil Environmental Laboratory

Abu Dhabi Quality and Conformity Council (QCC) declared 2016 as the 'Year of Environmental Laboratories'. It conducted a programme to check the competency of local laboratories, so as to

bridge any gaps and build the labs' capacities to achieve local and international accreditation. QCC is also currently preparing a central laboratory that will be benchmarked to international labs, acting as a reference to all local lab facilities. EAD has collaborated with QCC to provide a laboratory that fulfils all the required tests, including soil testing for agricultural purposes.

Initial Contamination Soil Investigation

Before 2016, there was no data on the naturally-occurring background concentration of contaminants (metals) in the soil of Abu Dhabi Emirate. To rectify this, a special investigation was conducted by EAD to ascertain the background concentrations of soil contaminants in the emirate's different soil types. This data was used as a benchmark in the development of the first Soil Contamination Guidelines for Abu Dhabi Emirate.

Soil Degradation Adaptation

Soil Salinity Project

Soil salinity is considered the most significant form of soil degradation in Abu Dhabi Emirate, particularly on agricultural land. Currently, EAD is conducting the Soil Salinity Inventory Project, over a three-year period between 2015 and 2018. During the project, soil salinity is being surveyed in 4,000 farms, as well as the implementation of a monitoring programme for salinity changes in 100 farms across the Emirate of Abu Dhabi. Data from this project will enhance EAD's soil database to provide decision-makers with up-to-date accurate information that informs policy on agriculture and the food sector. The final phase of the project will focus on the preparation of databases, maps and the development of a comprehensive action plan for management and reclamation of salt-affected farms.

EAD's emirate-wide soil survey was used to develop an integrated UAE Soil Information System

The soil survey provided vital data on the emirate's soil types and main factors causing degradation

Soil Quality Monitoring Programmes

EAD is developing annual programmes to monitor the quality of soil in industrial and residential land areas. These will determine baseline levels of soil contaminants and changes in soil quality, and determine the suitability of these areas for their current uses based on the Soil Contamination Guidelines.

Enabling Factors

Soil Survey Project

In 2009, EAD conducted an extensive emirate-wide soil survey [1]. Over a period of three-and-a-half years, the project included field surveys, collection of soil samples and their laboratory analyses, training, capacity building and the development of an integrated United Arab Emirates Soil Information System (UAESIS).

The UAESIS provides reliable information and data about the emirate's soils, and will ensure continuity in the flow of data for decision-making in the development and management of land in the emirate. The system also helps the government to raise environmental awareness and provides a foundation for future land and environmental research. This project also provided vital information on the types of soil in the emirate and the most important factors causing soil degradation. Due to the high value of the project's outcome, it was extended to include the Northern Emirates and was completed in 2012 [20].

Soil Archiving Facility

Situated in Al Faya, the soil archiving facility was established by EAD to benchmark with international standards and provide vital information about changes in soil quality over time. Offering both time- and cost-efficient soil sampling, the facility currently stocks 2,000 preserved soil samples available to relevant stakeholders for research purposes. The archiving facility has the capacity to store more than 25,000 soil samples under controlled optimal conditions to preserve their scientific value. All samples are managed through a geospatial database.

In 2016, EAD provided soil samples to the Federal Authority for Nuclear Regulation (FANR) in order to prepare UAE baseline data before the operation of Barakah Nuclear Power Plant.

4.5 Outlook

Sustaining soil quality is a strategic priority for Abu Dhabi Government

To ensure that the best use is made of suitable land in the emirate, it is necessary to understand and highlight the relationship between soils, the environment and planned land uses. This will also help in managing and reducing land degradation and some of the related environmental risks.

Valuable data about soil in Abu Dhabi Emirate is available, but needs to be actively utilised to serve environmental, social, educational and commercial objectives. EAD performed an extensive soil survey project in 2009, which is considered a rich data resource on soil in the emirate. It is the base for many current studies but there are still many gaps which need to be filled. For example, at present there are no policies or regulations to protect soil and prevent its contamination and degradation. There are limited studies showing the effects of anthropogenic activities on the quality of soil and its suitability for different land uses. There have been no programmes to study the changes in the quality of soil or the existence of contamination.

Abu Dhabi Government has marked this issue as a priority. One of the listed programmes in the Abu Dhabi Plan is to 'Protect biodiversity / Sustain soil and study the possibility of rehabilitating degraded areas'. EAD is responsible for conducting this programme, with multiple strategic objectives within its five-year plan (2016 to 2020) which have been put into action through a number of initiatives. These are targeted to enhance the existing legal framework and planning to consider soil quality. EAD will also spread awareness and play a vital role in ensuring proper management and remediation of contaminated land.

EAD has recently produced Soil Contamination Guidelines that are reflected in the Agency's permit and compliance system.

This now plays a major role in evaluating land and determining which areas have been contaminated or are vulnerable to contamination.

Continuous research and development of soil and land in Abu Dhabi Emirate is a necessity. Major soil pressures such as soil salinity, soil erosion, shallow hardpans and low soil fertility are limiting the soil and land development and need to be managed using international best management practices.

Supporting these initiatives and creating general awareness around soil quality will achieve a comprehensive environmental protection approach for land and soil and help provide a sustainable and safe environment for the next generation.

WATER RESOURCES

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KEY MESSAGES

DRIVERS

A low natural recharge rate, coupled with the increasing demand for water (linked to rapid socio-economic change), is driving reliance on non-conventional water resources in Abu Dhabi Emirate.

PRESSURES

Groundwater extraction for agriculture and forestry purposes exceeds the natural recharge rate, while domestic water consumption in Abu Dhabi Emirate is one of the highest in the world.

STATE

Over the last decade, the emirate's overall groundwater level has continuously declined, particularly in the Al Ain Region. The usable groundwater reserve (with total dissolved solids (TDS) of less than 15,000 ppm) had slightly increased in 2016 compared to 2005.

IMPACTS

The Al Ain Region is most affected by red zones (a groundwater level decline greater than 15 metres). These zones will increase reliance on the desalinated water supply, increasing the environmental burden from greenhouse gas (GHG) emissions and the discharge of brine water into the marine environment.

RESPONSES

A number of entities are working across different priorities to address the water stress issue within an integrated water management framework. This aims to achieve natural water conservation while minimising pollution.

5 Introduction

KEY INDICATOR OF CURRENT STATE: **2,013 Mm³** GROUNDWATER ABSTRACTED IN 2015 (PROJECTED VALUE)

Water Resources Management Challenge

Water is a sensitive and fundamental substance that acts as insurance for life on earth. It is, therefore, essential to acknowledge the importance of water resources and the ecosystem services that they provide, as well as natural ecosystems' reliance on water. Because of this strong connection, managing such a vital resource requires an integrated approach that acknowledges its availability for future generations in terms of quantity and quality.

In the Emirate of Abu Dhabi, water resource management is facing many challenges, particularly the scarcity of fresh water. Daily domestic water consumption in the emirate is 590 litres *per capita*, one of the highest in the world [1]. In addition, the expected increase in demand for water, due to the emirate's rapid economic and human development, is making the challenge even more serious.

The Local Policy Framework of Water Resources

The UAE Vision 2021 outlines the country's commitment to sustainable development, highlighting the preservation of the natural environment as a priority. In parallel, UAE Vision 2021 aims to achieve a balance between economic and social development in the emirates. In line with the priorities defined in the strategy, the UAE identified the water scarcity index as a key performance indicator (KPI) within the National Agenda as it progresses towards sustainability. The UAE Ministry of Energy (MoE) is the competent entity responsible for achieving the country's target water scarcity index by 2021.

In 2016, the Emirate of Abu Dhabi issued revised Law No. (5) on Groundwater Organisation for the emirate, replacing Law No. (6) of 2006. The revised law aims to strengthen the emirate's legal framework in order to achieve its objectives in conserving this natural resource and ensuring its optimal use. It extends the current legal mandate to cover activities such as illegal selling or transportation of groundwater, desalination unit installation and discharges of brine water into the environment. Additionally, it stipulates that metering is now required for farms, meeting technical criteria set by EAD.

Located in an arid region, the Emirate of Abu Dhabi has extreme natural water scarcity

5.1 State

The Emirate of Abu Dhabi is located in an arid region with extreme natural water scarcity. It relies almost exclusively on groundwater, desalinated water and, to a limited extent, on treated wastewater (see Figure 5.3). A heavy reliance on already scarce groundwater resources, mainly for irrigation in agriculture and afforestation, has resulted in threatening changes to groundwater quality and quantity. The assessment of these changes has been closely monitored through the established Groundwater Monitoring Network (GMN), which is managed by EAD through 1,506 monitoring wells distributed across the emirate (see Map 5.1).

The emirate's agriculture is heavily dependent on groundwater resources

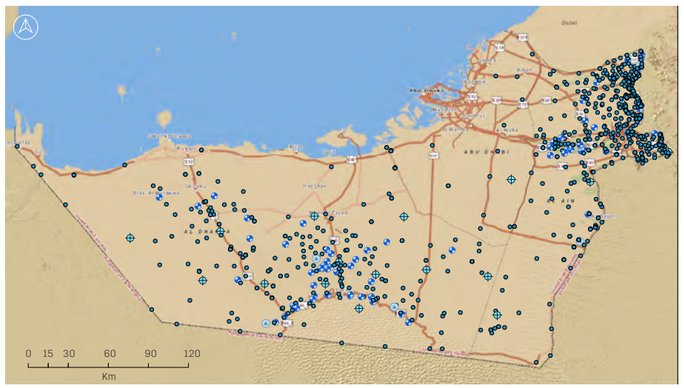
Groundwater Levels

Groundwater is the only source of natural fresh water in the emirate. However, due to the lack of rainfall and high levels of evaporation, the rate of groundwater recharge is insignificant compared to the rate of abstraction from shallow groundwater aquifer systems. As a result, the emirate's aquifers comprise mostly non-renewable fossil groundwater. The increasing demand for groundwater has led to reduced groundwater levels, influenced by the intensity of agriculture and afforestation activities in Abu Dhabi Emirate. Between 2005 and 2016, overall groundwater levels experienced a steady decline, with a severe decline in the Al Ain Region, mainly due to high groundwater withdrawal activities, resulting in depleted areas or 'red zones' (see Map 5.2).

The depletion of groundwater level is a serious issue due to the high rate of extraction. With a total of approximately 100,000 wells across Abu Dhabi Emirate, most of these are located in the Al Ain Region, which suffers from extreme groundwater level decline (see Figure 5.1 and Figure 5.2).

MAP 5.1 Distribution of Groundwater Monitoring Wells

- WATER LEVEL
- WATER LEVEL + QUALITY
- WATER LEVEL + QUALITY + RAIN
- WATER LEVEL + QUALITY + SOIL MOISTURE
- WATER LEVEL + QUALITY + WEATHER



SOURCE: EAD

Groundwater Salinity

Groundwater salinity is the concentration of dissolved solids in a defined unit of groundwater expressed as milligrams *per* litre. In Abu Dhabi Emirate, most of the groundwater in the surficial aquifers is brackish, saline or brine. EAD considers the emirate's groundwater as 'useable', with total dissolved solids (TDS) not exceeding 15,000 mg/l. In coastal areas and much of the area between Al Dhafra Region and Al Ain Region the brine water has higher levels of TDS, exceeding 100,000 mg/l. Fresh groundwater is found in surficial aquifers in the Al Ain Region and in Al Dhafra Region around the Liwa crescent. Besides the evident impact

FIGURE 5.1 Hydrograph of Monitoring Well GOW-017

LOCATION: Al Ain
UTM COORDINATES:
Easting - 379122
Northing - 2697432
MONITORING START DATE: 9/23/97
ELEVATION ABOVE MEAN SEA LEVEL 310.17M

SOURCE: EAD

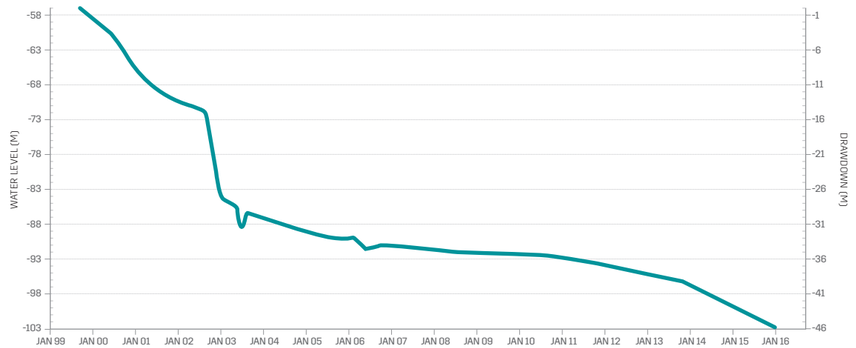
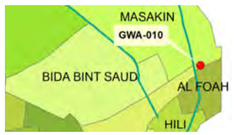
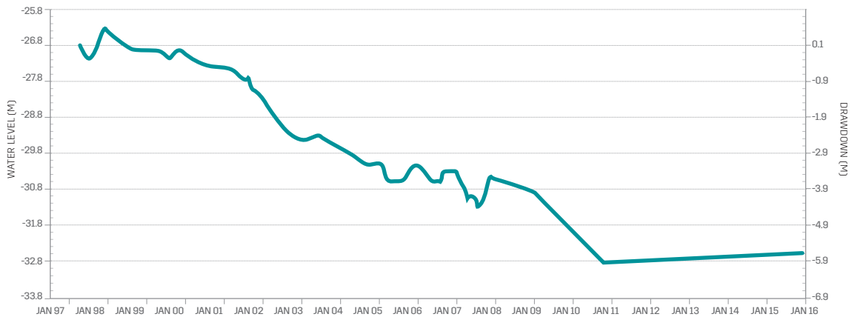


FIGURE 5.2 Hydrograph of Monitoring Well GWA-010



LOCATION: Al Khazna (Al Rodah)
UTM COORDINATES: Zone 40
Easting - 333968
Northing - 2670508
MONITORING START DATE: 9/19/99

SOURCE: EAD



Brackish groundwater is being desalinated in order to provide wildlife with fresh water

of evaporation on groundwater salinity, unsustainable groundwater abstraction and poor irrigation practice have also contributed to increasing salinisation of the aquifers in certain locations.

Map 5.4 and Map 5.5 show a direct comparison of changes in salinity between 2016 and 2008 in the Al Ain Region and Al Dhafra Region.

Groundwater Quality

Groundwater is a vulnerable resource in Abu Dhabi Emirate, and in many areas it is the only water resource available. Groundwater is also essential for sustaining wildlife in remote areas. However there is a need to better understand the details of the relationship between biodiversity and groundwater. Groundwater supplies are closely linked to soil condition and agricultural practices, with the inappropriate discharge of brine water from desalination units installed in farms and the use of fertilisers posing a real threat of contamination. In Abu Dhabi Emirate, the groundwater table ranges from just below the land surface (near sea level) along the coast to greater than 400 metres above mean sea level (MSL) in the regions around Al Ain. Regions of shallow depth to groundwater may represent areas of concern, being more susceptible to seawater intrusion and contamination from pollutants. The emirate's coastline also includes several small shoals, islands, lagoons, channels and deltas, an inner zone of intertidal flats (where algal mats are well developed) and broad areas of supratidal salt flats designated as 'sabkha' (flat, salt-crusted desert).

MAP 5.2 Change in Groundwater Levels Between 2016 and 2005

WATER LEVEL CHANGE (M)

- >11
- 5.5 TO 11
- 2.2 TO 5.5

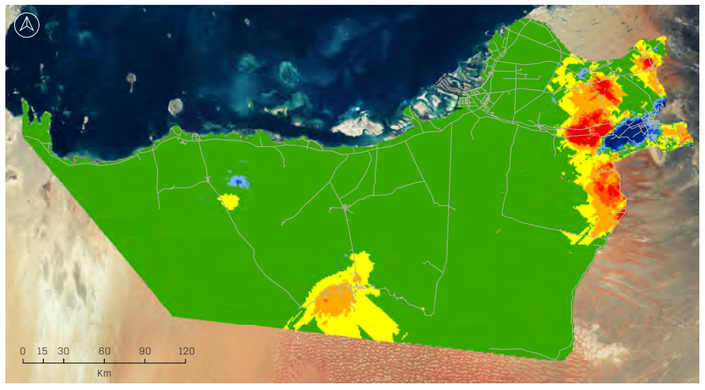
RISE

- -2.2 TO 2.2

STABLE

- -2.2 TO-5.5
- -5.5 TO -11
- -11 TO -13.7
- -13.7 TO -15
- > -15

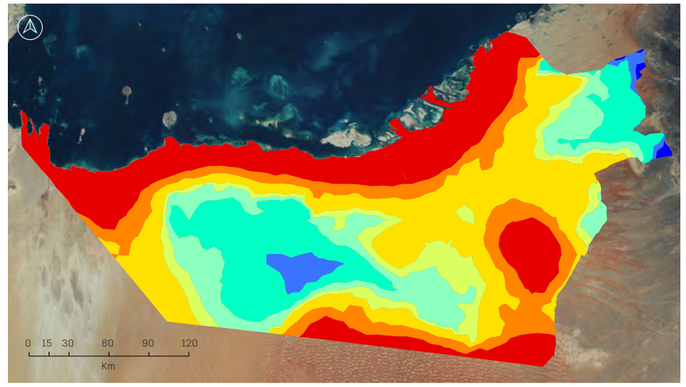
DECLINE



SOURCE: EAD

MAP 5.3 Groundwater Salinity Map, as of 2016 (mg/l)

- 1000 FRESH (WHO STANDARD)
- 1500 FRESH (UAE STANDARD)
- 4000 SLIGHTLY BRACKISH
- 7000 MEDIUM BRACKISH
- 10000 STRONGLY BRACKISH
- 25000 SALINE
- 50000 SALINE
- 100000 SALINE

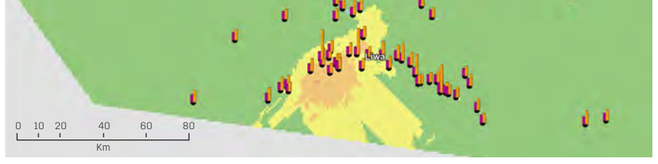


SOURCE: EAD

MAP 5.4 Trend of Groundwater Salinity (2008 to 2016) - Al Ain Region of Abu Dhabi Emirate

SALINITY HISTOGRAM

- 2008
- 2016



SOURCE: EAD

MAP 5.5 Trend of Groundwater Salinity (2008 to 2016) - Al Dhafra Region of Abu Dhabi Emirate

SALINITY HISTOGRAM

- 2008
- 2016

SOURCE: EAD

5.2 Drivers & Pressures

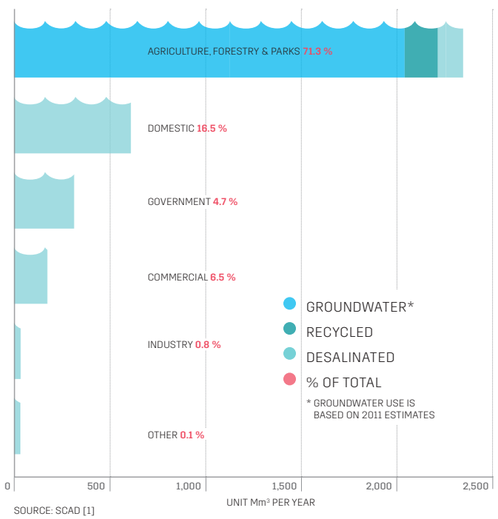
Water Consumption in Abu Dhabi Emirate

The Emirate of Abu Dhabi has an extreme *per capita* scarcity of renewable fresh water, and demand continues to rise. Groundwater and desalinated water account for 60 % and 35 % respectively of water use in the emirate, while the recycled water contribution is just 5 %.

Groundwater

Groundwater in Abu Dhabi Emirate is mainly used for agriculture and afforestation, accounting for a total withdrawal estimated at 2,013 Mm^3/year. Over the last few decades, intensive agriculture and irrigation of forests have altered the hydrogeological system in the emirate. Agricultural policy in the emirate poses a serious challenge in maintaining the current agriculture sector relative to the level of groundwater depletion and deterioration. With an estimated 24,000 farms now operating in Abu Dhabi Emirate, the number of plant holdings has increased rapidly in the last four decades, with more than 38 times more now operating than in 1971 [1].

FIGURE 5.3 Emirate of Abu Dhabi Water Use by Sector, 2016



SOURCE: SCAD [1]

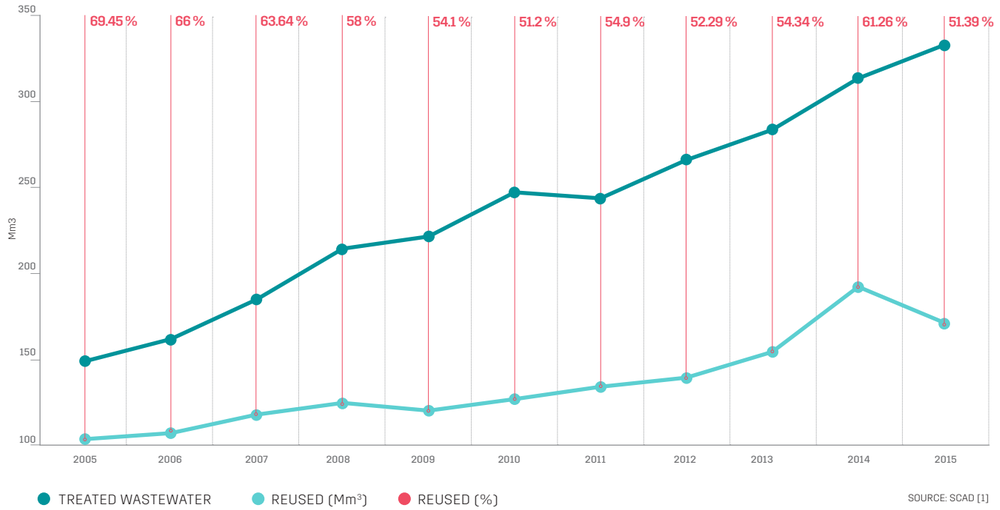
The increased demand for groundwater has also been fuelled by a number of policies in Abu Dhabi Emirate: food security, which aims to make the emirate less dependent on imported food and achieve 40 % local production levels [2]; 'greening the desert' policies, with a view to providing habitat for wild animals and stabilising the sand around roads; public parks to enhance the aesthetic value of outdoor spaces; residential and commercial megaprojects catering to the local population and a growing tourism industry; and rapid industrialisation driven by the Government's diversification efforts towards non-oil industries. Inefficient irrigation techniques and the inappropriate choice of crops have also contributed to the over-consumption of groundwater.

The impact of climate change on the hydrogeological cycle and groundwater use is not fully understood at present. However it is expected that changing weather patterns will be a pressure on the demand for groundwater in the emirate, with a slight impact on recharging aquifers in the Al Ain Region [3]. Further research is required to investigate the impact of a rise in sea water levels and its potential infiltration into the groundwater basin.

Desalinated Water

The Emirate of Abu Dhabi is estimated to have one of the highest rates of daily domestic water consumption, with a *per capita* consumption of 590 litres *per* day. There is a growing reliance on desalination as an alternative to the already extremely scarce groundwater; however this will put an extra burden on the environment. The current pattern of demand will lead the emirate to expanding its desalination capacity, which will have a greater negative impact on the environment in terms of GHG emissions and marine water discharge [4].

FIGURE 5.4 Treated Wastewater Reused (%) – 2005-2015



SOURCE: SCAD [1]

Although the domestic sector is responsible for 47.8 % of desalinated water consumption in the emirate, the agricultural sector has become more dependent on desalinated water, posting an annual increase of 255 % between 2014 and 2015 (from 55.26 Mm^3 to 196.18 Mm^3) [1].

Treated Waste Water

Recycled water from treated waste is not optimised due to an under-developed distribution system in the emirate. This is expected to be optimised as an alternative water source for non-drinking purposes, including the irrigation of forests and some crops [5]. Currently only 51 % of all treated water is recycled (see Figure 5.4), while the rest is discharged into the environment. The current return-to-sewer rate is only 28.6 %, meaning that only a small amount of the total desalinated water used goes back into the sewers to be then treated, despite the fact that approximately 96 % of the population is connected to the system [5]. High outdoor usage may explain why the return-to-sewer rate is so low.

Water Losses and Inefficiencies

According to the Regulation and Supervision Bureau (RSB), the regulator for the water and electricity sector in the Emirate of Abu Dhabi, around 20 % to 30 % of desalinated water production is lost through transmission and distribution. While transmission network losses are less than 2 %, distribution networks are responsible for 21 % of water losses in Abu Dhabi Emirate, and 3.7 % in Al Ain [6].

In addition, only 28.6 % of consumed desalinated water in the emirate returns to the sewage system. This is a low percentage compared to regional benchmarks, and is due to technical and commercial losses. Lastly, around 49 % of treated sewage water produced in 2015 was discharged into the desert or Gulf, due to underdeveloped transmission and distribution systems [1].

Trans-boundary Groundwater Aquifers

With the UAE bordering Oman and Saudi Arabia, groundwater found in non-renewable aquifers is a critical resource for agriculture in each of these three countries. Shared groundwater resources are evident in the Al Ain Region, towards Oman's Al-Buraimi region [7]. With unsustainable agricultural practices and over-exploitation of resources contributing to the depletion of aquifers, a proper understanding of trans-boundary groundwater aquifers is essential for the management of this resource.

5.3 Impacts

Ecological Impacts

Air Pollution and GHG Emissions from Desalination

GHG emissions from fossil fuel-powered desalination plants contribute to climate change and air pollution [4]. According to SCAD, the emirate's total fuel consumption in water and electricity activities increased by 9 % from 2014 to 2015 due to the coupling of energy and water, leading to an increase in emissions of GHG and air pollutants. Levels of sulphur dioxide (SO_2) become particularly acute when there is a need to use oil instead of natural gas as a fuel source. According to GHG Inventory 2012, the water and electricity sector is the largest emitter of carbon dioxide (CO_2) emissions (33 %) [8].

Impact on Groundwater and Soil

The agricultural sector consumes the most groundwater by far, followed by forestry and amenities. The improper use of inorganic fertilisers leads to nitrate leaching into the soil and groundwater, as well as soil deterioration and salinisation. Soil contamination is an extremely underestimated issue, with a lack of awareness contributing to the improper discharge of brine water into the emirate's soil, forming 'crystal' patches which are beds of salt.

Marine Pollution and Loss of Biodiversity

Desalination and treatment activities threaten marine biodiversity due to the discharge of brine and thermal water into the marine environment. Brine water discharge is approximately 9-10 m^3 *per* 1 m^3 of desalinated water produced. Chemicals such as chlorine and copper, which are harmful for the marine habitat and biodiversity, remain in the brine. This issue is also intensified due to the recycled water that is also discharged into the sea, affecting marine life, while a change in groundwater levels due to over-abstraction may threaten terrestrial biodiversity.

Marine water quality can be affected by desalination processes, with potential impacts on human health

Economic Impacts

Cost of Desalination

Ecosystem deterioration caused by treatment and desalination practices could affect biodiversity in the Arabian Gulf and the ecosystem services it provides. As a result, fisheries could be affected, with diminishing fish stocks. According to Abu Dhabi Water Strategy 2015-2020, in 2011, stocks were estimated to be 529 kg *per* km^2 compared with 1,735 kg *per* km^2 in 2002. That is, fish stocks decreased by more than two-thirds in just nine years [9]. This may have an economic impact on one of the fundamental components of food security in the region.

Contribution of Agricultural Production to GDP

Currently agriculture is responsible for more than 60 % of groundwater use in Abu Dhabi Emirate; however its contribution to the emirate's GDP is less than 1 %. Agriculture is not a sustainable sector, therefore minimising water use while improving crop productivity is necessary to achieve food security targets while reducing water use. With the agricultural and forestry sectors being the main consumers of groundwater resources in Abu Dhabi Emirate, SCAD data on the percentage distribution of GDP in 2014 shows that agricultural economic activities contribute to only 0.6 % of the emirate's GDP.

Social Impacts

Health Impacts

There is a potential risk to human health from exposure to low-quality water. With marine water quality being affected by water desalination and treatment practices, the emirate's coastal waters could suffer from algal blooms as a result, especially due to insufficient tidal flushing around Abu Dhabi Island. Of particular concern is direct contact with sewage water and groundwater with high concentrations of nitrate, fluoride, boron and chromium. At present, there is insufficient information to assess the burden of disease due to groundwater contamination from factors such as waste sites.

National Security Impacts

Long-term Availability of Water Resources is at Risk

If the current rate of abstraction continues, groundwater in Abu Dhabi Emirate may be depleted within a few decades. Currently there is an excess capacity of desalinated water of 15.1 %. However, if no further investments are made, a deficit capacity of 28.6 % is forecast by 2030.

Gas limitation is another threat to the long-term availability of desalinated water. According to SCAD data, fuel consumption in the electricity and water sectors is increasing. Natural gas consumption increased by 9.4 % between 2014 and 2015, rising from 618,009 Mscft to 676,155 Mscft [1]. The emirate is also increasing the use of other types of fuels, such as crude oil and gas oil, to meet the increasing demand.

Water Security Risks

Abu Dhabi Emirate currently has a low storage capacity for desalinated water. However, after the completion of the strategic water reserve project by the end of 2017, the emirate's storage capacity will be increased to 90 days. Sea water desalination is challenged by high sea water salinity, elevated sea water temperatures and the abundance of algae, and has high exposure to any risks associated with oil spills and marine pollution.

5.4 Responses

Building a Comprehensive Understanding of Groundwater Resources

Well Inventory Project

The Well Inventory Project was established by EAD with the aim of providing information on well characteristics, water table, salinity, and water pollution from across Abu Dhabi Emirate. The project also includes additional information on soil analysis. The project is divided into three stages:

- STAGE 1 - an inventory of all wells in the emirate (operational and non-operational)
- STAGE 2 - collection and analysis of soil samples for the purpose of developing soil classification
- STAGE 3 - preparation of the first Atlas of Ground Water in Abu Dhabi Emirate.

Groundwater Monitoring Network Optimisation

EAD is working towards achieving a comprehensive understanding of groundwater resources in Abu Dhabi Emirate, by integrating groundwater monitoring networks under one umbrella to strengthen coverage. The agency is also building a digital model of the underground reservoir, which targets the extreme depletion zones of the Al Ain Region.

Achieving Reduced Water Use and Improving Sector Productivity

Crop Calculator

In a joint initiative with the Abu Dhabi Food Control Authority (ADFCA), EAD developed a 'crop calculator' to optimise water used to irrigate crops. The crop calculator will be used as a guide for permit processes by allocating a defined volume of water for farms.

The Well Inventory Project is an EAD initiative to provide information on well characteristics, the water table and pollution levels

EAD aims to achieve a comprehensive understanding of the emirate's groundwater resources through a monitoring programme

Review of Subsidies

Subsidies for the cultivation of crops requiring high water intensity were reviewed in 2010. As a result, recommendations were made to discourage farms growing those crops (in particular Rhodes grass) by removing subsidies. There is an opportunity to continue a further review of subsidies to promote positive agriculture practices, optimising and improving productivity levels while minimising water use.

Maximising the Use of Treated Wastewater

The Abu Dhabi Sewerage Services Company (ADSSC) is working on maximising the use of treated wastewater in the emirate. Working in partnership with EAD, the aim is to reduce the stress on natural resources and provide recycled wastewater to irrigate the emirate's farms and forests. At present more than 49 % of produced tertiary treated wastewater is discharged into the environment, with both economic and environmental impacts.

Balancing Water Use Within Sustainable Limits

EAD and ADFCA are working together to address the unsustainable use of groundwater in the agriculture sector. The two entities are exploring policy options to reduce groundwater usage while meeting food security priorities, by promoting productive uses within defined sustainable limits. The study will be undertaken as part of a 'water budget' programme in collaboration with academic institutions.

Using New Innovative Technology in Agriculture

EAD and ADFCA jointly developed a demonstration centre for new innovative technologies in agriculture and food production (such as advanced hydroponic systems) to increase efficiency in the use of water resources in the agricultural sector while increasing productivity levels. The centre was commissioned in 2016.

5.5 Outlook

Looking Ahead

Abu Dhabi Vision 2030 focuses on the conservation of water resources and their efficient management. The UAE's precious water resources were further reinforced as a strategic priority through the UAE Vision 2021, which highlights water stress as a key national agenda.

Further Response

Traditionally, the region's population relied on 'Aflaj', the water run-off from mountains, to meet its water requirements. With a limited quantity of water available, living conditions in the region were very harsh. Today, groundwater has been excessively exploited through drilling, with deeper wells found mainly near the Al Ain Region. The condition of Abu Dhabi Emirate's groundwater is steadily deteriorating, both in term of its quantity and quality, and further investigation is needed to understand any impacts this may have on the emirate's biodiversity.

EAD, along with key stakeholders, is taking extraordinary measures to address the groundwater challenge, while the Abu Dhabi Government is aware of the importance of groundwater resources as part of the emirate's natural heritage. In 2016, the Revised Law No. (5) was issued, expanding the emirate's regulatory capacity in order to achieve the targets for the conservation of natural resources, as stated in the Abu Dhabi Environment Vision 2030.

EAD is expanding its activities in order to gain a comprehensive understanding of aquifer conditions. There are now more than 1,300 groundwater monitoring networks across the emirate, and the agency's largest well inventory project will enable EAD to account for all operational and non-operational wells, water salinity, water levels, water pollution and additional information to assist soil classification. ADFCA and Abu Dhabi Farmers' Services Centre (ADFSC) are also exploring innovative initiatives to reduce water pressures in the agriculture sector through joint initiatives. Examples include: bio-saline agriculture; alternative irrigation technologies, such as hydroponics, and greenhouses to replace open-field agriculture; and the showcasing of model farms in collaboration with EAD to raise farmers' awareness of sustainable farming practices.

Through a number of different entities, the emirate has made significant investments in technical innovations to improve groundwater levels. These include the Strategic Water Reserve project, where water is stored for up to three months in underground aquifers, and the adoption of solar-powered desalination units to produce higher quality water from mostly brackish and saline groundwater, which extends the capacity of water available for crop irrigation.

In 2015, a new water tariff was introduced to raise awareness in the domestic and commercial sectors of a more conscious use of desalinated water. This will help reduce the environmental burden from the water and electricity production sectors.

Preserving precious groundwater resources is a strategic priority within the Abu Dhabi Vision 2030

MARINE WATER QUALITY

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Assistant Scientist – Marine Water Quality
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Environment Agency – Abu Dhabi

KEY MESSAGES

DRIVERS

Population growth and economic development are driving a change in the state of marine water quality.

PRESSURES

Coastal development, industrialisation and tourism and their associated activities are a result of these drivers.

STATE

Marine water quality in the Emirate of Abu Dhabi is generally good. However, there is a trend toward increasing eutrophication, primarily from coastal industry and treated wastewater discharges in Abu Dhabi City areas.

IMPACTS

The impacts on mainland coastal areas appear to be stable, except for certain confined areas. Previous impacts, measured in terms of fish kills and beach closures, are diminished. However, incidences of harmful algal blooms, which can negatively affect human health and marine organisms, appear to be increasing.

RESPONSES

Management interventions aim to limit the impacts mentioned above. These include water quality monitoring, proposed ambient marine water and sediment quality limits, and regulation of dredging and industrial discharges.

6 Introduction

KEY INDICATOR OF CURRENT STATE: **94 %** OF MONITORED SITES MET GOOD MICROBIAL WATER QUALITY STANDARD IN 2015

The Arabian Gulf coastline of Abu Dhabi Emirate is approximately 700 km [1], accounting for 76 % of the entire Arabian Gulf coastline in the UAE. The emirate's numerous desert islands are home to dynamic, diverse and complex ecosystems with rich biodiversity.

The marine environment of Abu Dhabi Emirate contributes significantly to the economic and social wellbeing of the population. Prior to the discovery of oil and gas, the region's main economic pillars included fishing, pearl diving and sea trade. Today, the emirate's dependence on coastal activities has expanded, with the development of major recreational, industrial, transportation and tourism activities.

As the coastline continues to be impacted by rapid economic development and urbanisation, protection of marine water quality in the Emirate of Abu Dhabi is essential to maintaining the health of fisheries, recreational beaches, coral reefs, mangrove forests and seagrass beds, as well as iconic native species such as Dugong and Sea Turtles [2, 3, 4].

As a result, preserving Abu Dhabi Emirate's marine water quality is of particular importance for sustainable coastal development.

With 700 km of coastline, the marine water quality in Abu Dhabi Emirate is generally good

6.1 State

The condition of Abu Dhabi Emirate's marine waters, as reflected in their physical, chemical and biological characteristics, is generally good. However, increasing trends in the concentrations of nutrients (nitrate, phosphate) and chlorophyll-a indicate that eutrophication is an ongoing threat to water quality in the emirate, as it is in many other nations around the world [5, 6]. EAD has taken significant steps to curtail the continued elevation of nutrients in Abu Dhabi Emirate's marine waters, and the ongoing execution of regulations and limits should significantly abate this issue in the coming years. The implementation of ambient marine water quality limits will help improve and safeguard the health of the emirate's marine waters. Knowledge gleaned from monitoring programmes (see Map 6.1) will assist in the design and development of strategies for reducing eutrophication.

Elevated Nutrient Levels

Nutrients found in marine waters are essential for sustaining marine flora and fauna. Their presence is beneficial at a certain level; however, an excessive amount of nutrients may lead to serious water issues (see the Impacts section). Since 2011, nutrient levels along the emirate's coastline are considered to be within an acceptable range. This is with the exception of high concentrations of nutrients which appear to be in confined areas. This is the result of poor circulation, in addition to treated sewage effluent (TSE) disposal into the marine environment. Around 400,000 m^3 of TSE *per* day is disposed into South Mussafah Channel [7]. As a result, the mean concentration of chlorophyll-a in these confined areas is also very high compared to the other locations. This is in addition to the high concentration of nutrients which act as fertilisers for chlorophyll-a containing phytoplankton (algae).

Confined areas have lower water clarity due to poor water circulation and the impacts of industrial discharges, dredging and ship repair activities. These activities cause sediments to become re-suspended in the water, leading to increased turbidity. Poor water clarity can also be caused by high concentrations of nitrate and phosphorus, stimulating algal bloom formation. Maximum water clarity is observed in the largely pristine Marine Protected Areas in the Al Dhafra Region of the emirate.

MAP 6.1 MWQ Monitoring Stations

CONFINED AREAS
- S001 Al Salamiyah Channel
- S002 Mussafah South Channel
- S003 Mussafah Industrial Area
- S004 Mangrove Area - Eastern Corniche

PUBLIC BEACHES
- S007 Al Bateen Beach
- S008 Emirates Palace Public Beach
- S009 Corniche Beach

PORTS AND MARINAS
- S0010 Intercontinental Jetty
- S0011 Port Mina Zayed
- S0012 Ruwais

DESALINATION PLANTS
- S0013 Um Al Nar
- S0014 Taweela
- S0015 Mirfah

MARINE PROTECTED AREAS
- S0016 Marawah
- S0017 Al Basam
- S0018 Butinah
- S0019 Al Yasat

- S0023 Reference

SOURCE: EAD

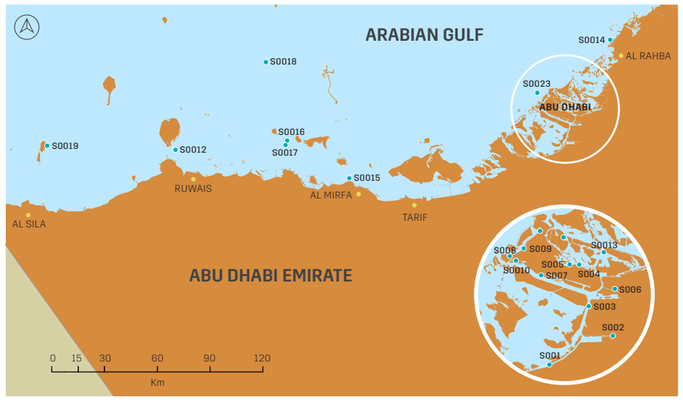
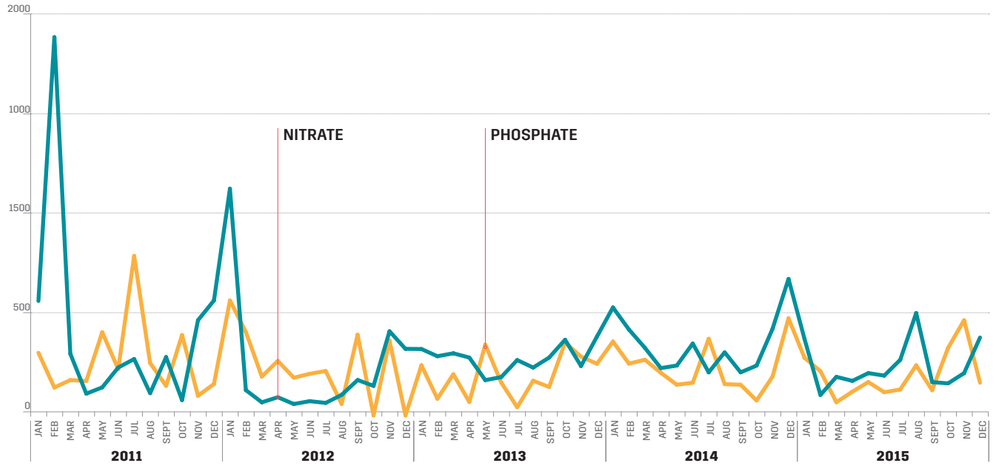


FIGURE 6.1 Monthly Mean Nitrate & Phosphate Levels in Marine Water in Abu Dhabi Emirate, 2011-2015



SOURCE: EAD, 2016

FIGURE 6.2 Monthly Mean Ammonia Levels in Marine Water in Abu Dhabi Emirate, 2011-2015

SOURCE: EAD, 2016

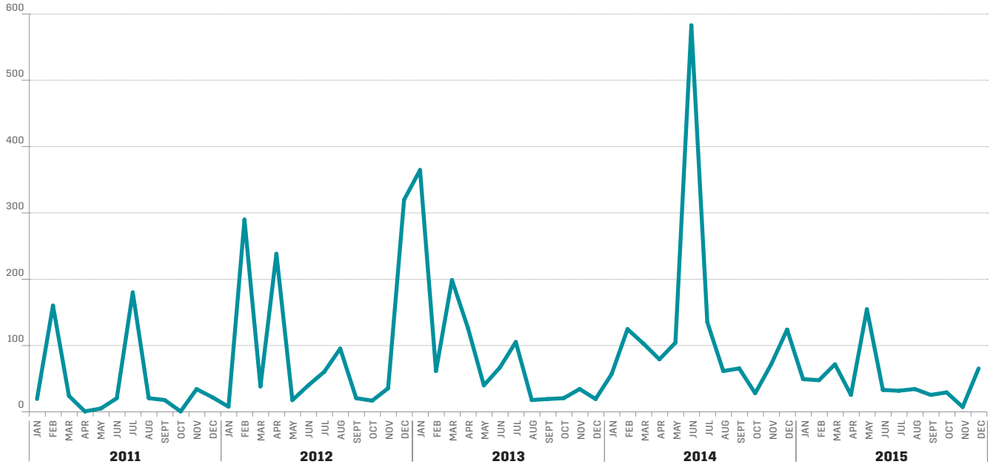
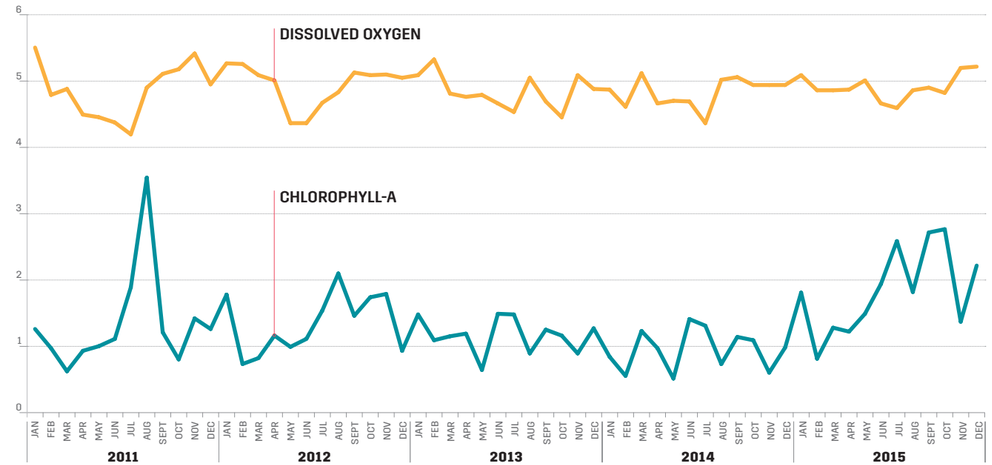
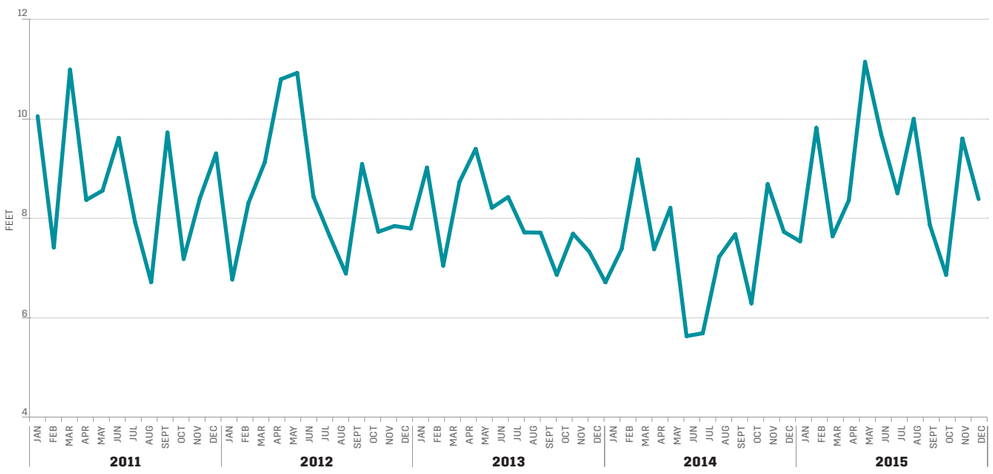


FIGURE 6.3 Monthly Mean Dissolved Oxygen & Chlorophyll-a Levels in Marine Water in Abu Dhabi Emirate, 2011-2015



SOURCE: EAD, 2016

FIGURE 6.4 Annual Mean Marine Water Clarity in Abu Dhabi Emirate, 2011-2015



SOURCE: EAD, 2016

Increasing coastal development and construction activities exert pressure on marine water quality

EAD monitors levels of 39 parameters in selected ecologically important areas to assess eutrophication due to nutrient loading, including: nitrate (see Figure 6.1); phosphate (Figure 6.1); ammonia (Figure 6.2); chlorophyll-a (Figure 6.3); dissolved oxygen (DO) (Figure 6.3); and water clarity (Figure 6.4).

EAD's monitoring programme uses a Marine Water Quality Index on an ongoing basis to indicate the status of marine water quality related to eutrophication and microbial levels in water and heavy metals in sediment (see Figure 6.5, Figure 6.6 and Figure 6.7 respectively). Scores are grouped into three condition rating categories: 'Good' (a score of 75 and higher), 'Fair' (a score of 50 to 74), and 'Poor' (a score of 0 to 49).

As indicated in Figure 6.6, marine water microbial levels are very low, indicating that beach waters are generally safe for recreational use. However, routine monitoring of all beaches and other recreational areas should be undertaken to ensure that public health is protected.

Generally, eutrophication is less prevalent in waters distant from Abu Dhabi City and industrial areas. However, there are increased nutrient levels due to limited water circulation in confined areas such as channels and marinas (see Figure 6.5).

Additionally, nutrient levels in some Marine Protected Areas have risen slightly in recent years. This phenomenon warrants investigation to ascertain what factors (whether natural or anthropogenic) may be causing such changes at these remote and protected locations, where pristine water quality is generally the norm.

Marine water quality monitoring data collected by EAD over the past 10 years on heavy metal contamination in the water column and sediments, shows that mean metal concentrations in sediment are low and relatively stable or modestly decreasing around Abu Dhabi City, and are very low in Marine Protected Areas (see Figure 6.7).

6.2 Drivers & Pressures

Drivers

As described in Chapter 2 – Driving Forces of Environmental Change, the Emirate of Abu Dhabi has a high population growth rate, which puts demand on resources. Economic development generates an increase in commercial shipping traffic and the need for dredging to deepen existing channels and create new channels and harbours. Effluent discharges from construction projects and industrial facilities can introduce excess nutrients, sediments and chemical contaminants into marine waters, impacting environmental health. Economic development and population growth also spur demand for increased electric power and potable water from power generation and seawater desalination plants, as well as a greater need to treat increasing volumes of wastewater.

Pressures

Current pressures on the emirate's marine waters include: coastal development and construction activities; commercial shipping and port development; increased wastewater discharges; surface run-off; industrial and wastewater discharges; desalination plant discharges; and atmospheric deposition [4]. Climate change and a rise in sea level may also interact synergistically with these other pressures to modify the state of marine water quality.

In addition to a loss of important habitats, such as coastal lagoons and mangroves and their associated ecosystem services (benefits that humans derive from nature), activities associated with coastal development (such as dredging) and other types of construction can result in excess sediments in the water column. This reduces light for seagrasses and can potentially smother benthic organisms, such as corals. Dredging can cause the presence of excess sediment in the water column, which may activate toxic algal cysts and release sediment pollutants. A restriction of water flow, due to construction or the creation of limited or no-outflow channels, also reduces marine water circulation and flushing, resulting in high pollution concentrations due to slow dispersion.

Pollutants from roads and other impervious surfaces, as well as fertiliser run-off from landscape maintenance and agriculture, have the potential to be swept up by stormwater, water from vehicle washing, and other water-related activities, and be carried into waterways or stormwater drains that discharge into waterways.

Abu Dhabi Emirate has thriving industrial facilities, including power generation, iron and steel works, and many other factories and plants. These are concentrated mainly in the Industrial City of Abu Dhabi (ICAD), Mussafah Industrial Area, Khalifa Industrial Zone Abu Dhabi (KIZAD) and Al Ain. Effluent discharges from industrial facilities may introduce excess nutrients, sediments, heavy metals and other potentially toxic chemical contaminants into waterways, which can alter the pH level of the waters. These pollutants have the potential to reduce biodiversity, create conditions which lead to fish kills and reduced fish landings, and affect the water's ability to be used in processes such as desalination and cooling. Heavy metals and other toxins may accumulate in fish and seafood, potentially posing a risk to humans through consumption.

An increasing human population in Abu Dhabi Emirate also means greater volumes of wastewater discharges through outfalls. These discharges potentially introduce pathogens and nutrients into the marine environment, which can affect industrial and recreational uses.

Abu Dhabi Emirate has seven major desalination plants which are capable of producing nearly 3.2 billion litres *per* day [7]. In addition, several smaller desalination plants line the emirate's coast. Desalination plants discharge high-temperature brines, detergents and metals into marine water, which can adversely affect marine habitats, such as coral reefs and seagrass meadows. The intakes of desalination plants can kill marine fauna by impinging these organisms on intake screens. In addition, the larvae of fish and other marine invertebrates, including corals, molluscs and crustaceans, can be entrained in the water cooling system of desalination plants and killed by heated water, which has a negative effect on the adult populations of these species.

In 2014, the emirate's waters hosted approximately 35,000 commercial vessels and nearly 100 cruise ships [8]. Shipping can result in the release of several types of discharge into the marine water, such as ballast water, wastewater, ship anti-fouling chemicals (e.g. copper or detergents), oil and grease, and fuel spills. Insufficient shore-side facilities for sewerage and waste transfer in marinas can also cause waste to be dumped at sea.

Dredging places additional pressures on marine water quality because it can re-suspend bottom sediment into the water column, releasing contaminants and re-suspending algal cysts, thereby reducing water clarity.

In addition, the transfer and release of ship ballast water can cause the release of exotic species of phytoplankton and marine larvae of fish, crustaceans, molluscs and zooplankton, which may become invasive alien species in the Arabian Gulf.

Atmospheric deposition (when pollutants are transferred from the air to the earth's surface) has been shown to be a significant source of pollutants to coastal waters in many areas of the world [9]. Pollutants (trace metals, toxic organic compounds and nutrients) can transfer from the air into the water through rain, falling particles, dust events and the absorption of gaseous pollutants into the water.

FIGURE 6.5 Eutrophication Marine Water Quality Index Results, 2011-2015

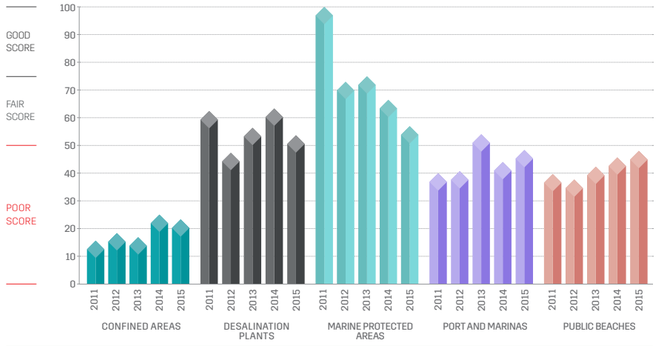


FIGURE 6.6 Microbial Index, 2012-2015

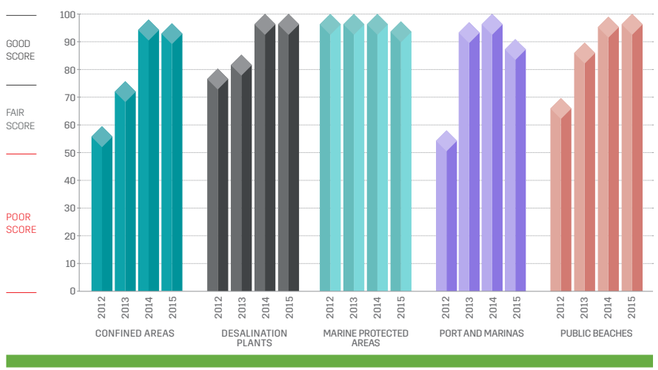
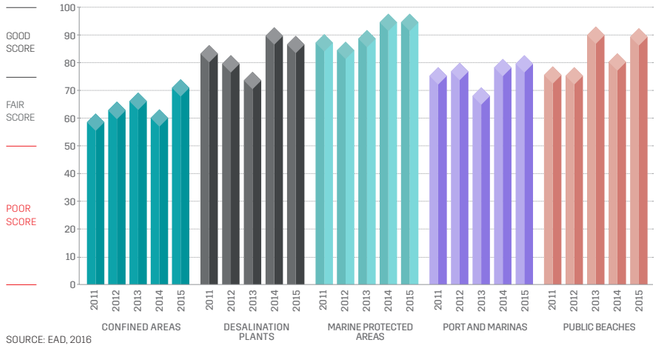


FIGURE 6.7 Heavy Metals Marine Water Quality Index Results, 2011-2015



SOURCE: EAD, 2016

6.3 Impacts

EAD has implemented a robust marine water quality monitoring programme to protect the marine environment

Eutrophication

The changes in or deterioration of marine water quality in Abu Dhabi Emirate influences not only the marine ecosystem but also the emirate's economy. Currently, eutrophication (the excessive nutrient enrichment of a water body) is a major concern in the emirate's waters, because it stimulates algal growth, causing subsequent environmental issues.

If moderate levels of nutrients enter a body of water, then the consumer community (such as fish, shellfish, benthic organisms and bacteria) can benefit from the added nourishment. Increasingly, however, human activities are over-enriching coastal waters with excessive amounts of nutrients, particularly various compounds of nitrogen and phosphorus [5, 10]. As a result, phytoplankton populations increase rapidly to levels that exceed the consumption capacity of the community of zooplankton, shellfish and fish, which can lead to outbreaks of harmful algal blooms (HABs). The excess, unconsumed plant material can result in secondary problems such as diminished water clarity and dissolved oxygen (DO) depletion in bottom waters (i.e., hypoxia) as the phytoplankton population dies and sinks to the bottom, where it is decomposed by bacteria. Hypoxic waters often result in the death of shellfish and other aquatic organisms that are unable to tolerate the low oxygen concentrations.

Harmful Algal Blooms

HABs occur when phytoplankton species increase rapidly to high population numbers, with damaging effects on other marine organisms or humans. Although HABs may form as a result of natural conditions, severe eutrophication in marine waters may also result in favourable conditions for the formation of HABs.

Some HAB species produce toxins harmful to other marine organisms and to humans [11]. HABs can cause fish kills and shellfish poisoning and can disrupt the normal operation of desalination plants by blocking seawater filtration systems.

HABs have been responsible for mass mortalities of fish worldwide, causing catastrophic impacts to aquaculture and local fish and shellfish economies [11]. Fish kill incidents have been recorded in the waters of Abu Dhabi Emirate since 2002. EAD recorded the highest number of fish kill incidents in 2011. However, not all fish kill incidents in the emirate's waters are caused by HABs.

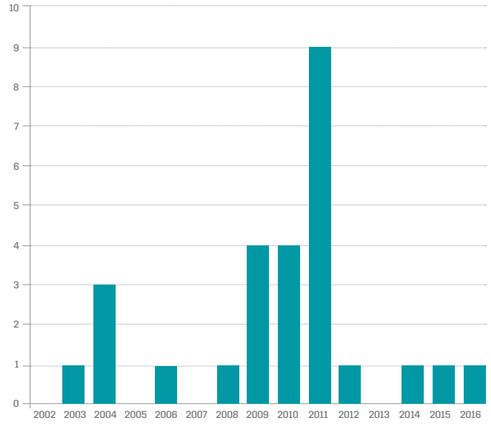
Additionally, toxic and nuisance blooms may limit recreational and industrial use of marine waters. The UAE has experienced severe and widespread HAB outbreaks in the Arabian Gulf and the Gulf of Oman in 2008 and 2009. The number of HAB incidents has been increasing in Abu Dhabi Emirate's waters since 2002, reaching up to 30 incidents during 2015 (see Figure 6.9).

In particular, water quality analyses have routinely shown that the Mussafah South Channel is impacted by nutrient enrichment, low DO concentrations in bottom waters, phytoplankton blooms and fish kill incidents throughout the year [13]. These outbreaks have increased over the past decade and are likely associated, in part, with the eutrophic conditions caused by discharges into the marine environment.

Health Impacts

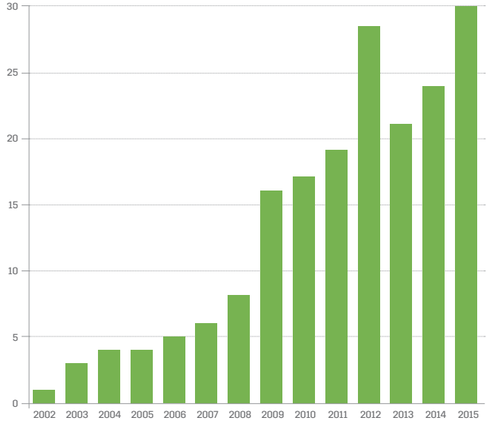
Monitoring programme results indicate that Abu Dhabi Emirate's waters have historically enjoyed excellent microbial water quality, including all public beaches. In line with the generally good microbiological quality of marine water environments in the UAE, the expected effect on human health is low.

FIGURE 6.8 Incidents of Fish Kill in Abu Dhabi Emirate



SOURCE: EAD, 2016

FIGURE 6.9 HAB Incidents in Abu Dhabi Since 2002



SOURCE: EAD, 2016

6.4 Responses

What We Aim to Achieve

In line with Abu Dhabi Environment Vision 2030, EAD's main goals are to protect the emirate's marine environment and maintain good marine water quality, so as to protect human and marine life and the economy.

EAD implements a robust marine water quality programme to continuously develop and improve the holistic understanding of the current status and changes in marine water quality. Data gathered and analysed by EAD guides decision-making by key stakeholders, with EAD also developing and enforcing regulations and policies to protect marine water quality from the sources of impacts. Additionally, EAD develops and implements effective response plans to mitigate the impacts of marine water quality emergencies, such as algal blooms, sewage spills and fish kills.

As part of the monitoring programme, samples are taken from locations along the coast to analyse pollution trends

EAD serves as the secretariat organisation for the Government of Abu Dhabi's Higher Committee on Marine Water Quality. Founded in 2012, this comprises the top leadership of all Abu Dhabi Government entities that have responsibility for monitoring, regulating and protecting the emirate's marine water quality. The Higher Committee develops and oversees the design and implementation of inter-agency marine water quality protection initiatives.

In combination with Abu Dhabi Sewerage Services Company's (ADSSC) planned Strategic Tunnel Enhancement Programme (STEP), which is anticipated to improve sewage treatment capacity and divert treated water to be used for irrigation, EAD aims to reduce the probability and extent of such marine water quality emergencies.

Sustaining healthy marine water quality requires the support of all stakeholders and the general public in Abu Dhabi Emirate. Therefore, one of EAD's key initiatives is to increase awareness of the importance of maintaining high marine water quality and protecting it from deterioration. EAD has developed several water quality outreach materials, such as reports and press releases, to help inform the public about the significance of Abu Dhabi Emirate's marine water quality.

Existing Responses

The importance of Abu Dhabi Emirate's marine water quality is rising with the increasing developmental pressures on the marine environment. In 2006, EAD commenced its ongoing Marine Water Quality Monitoring Programme (MWQMP) to ensure that the emirate's coastal waters remain safe for people, plants and animals.

The backbone of the MWQMP is the collection of marine water and sediment samples from several locations along the emirate's coast. In-situ analysis is performed to measure physical parameters, followed by additional laboratory testing for nutrients, organics, microbes and heavy metals. The objective is to detect and analyse both historical and present trends in pollutant levels and the resulting pressures on the marine environment.

To ensure that the MWQMP continues to meet the current and future needs of Abu Dhabi Emirate, periodically EAD conducts comprehensive reviews of the monitoring stations, parameters, sampling protocols and analysis methods. The latest network review was completed in 2015. The analysis and reporting of water quality data is performed to enable EAD to make science-based decisions that protect marine resources from the environmental impacts of rapid development, as well as support EAD's enforcement operations. This includes compelling developers to mitigate and, in some cases, halt actions which could result in unreasonable environmental impacts.

EAD develops and publishes quarterly and annual marine water quality reports which communicate the results of the MWQMP.

In addition to the MWQMP, EAD has developed an early warning system to forecast the formation of HABs, in response to the severity of this threat. The system relies on automated buoys which are equipped with sensors that collect data on ambient water characteristics every hour, seven days *per* week. This data is transmitted in real time to EAD headquarters for evaluation. Similar automated marine data buoys are currently available under Abu Dhabi Water and Electricity Authority (ADWEA), Department of Urban Planning and Municipalities (DUPM) and Abu Dhabi Ports Company (ADPC), so as to provide a continuous data stream on marine water quality parameters.

Every five years EAD carries out a comprehensive survey to investigate marine water and sediment quality across the entirety of Abu Dhabi Emirate's territorial waters. Measurements and samples are taken at the surface and depth intervals on a 17 km grid, recording data on more than 30 water quality parameters at 100 offshore sites. Concurrent sediment samples are also collected from each site for heavy metal analysis. The data generated from this transect study is analysed and compared to long-term monitoring data. By covering the full extent of the coastal waters, EAD's research provides a reference point for future years and supports the development of ambient marine water quality standards.

EAD recently developed recommended ambient marine water and sediment quality limits, which are based on data available from the MWQMP. Limits were developed for three types of priority pollutants: heavy metals, organics and microbial parameters. An extensive literature review was conducted, and a list of international standards for microbiological indicators in different countries was compiled. Best international practices and other regional references for marine water quality standards were evaluated. The limits are categorised for two designated uses: Marine Protected Areas and General Uses, including all areas around marine protected areas. In cooperation with the Health Authority – Abu Dhabi (HAAD), EAD developed microbiological limits for ambient marine water in the emirate.

EAD regulates industrial facilities and development project sites by issuing environmental permits and compliance inspections. Facilities and projects are evaluated by EAD assessors who provide recommendations on the mitigation of environmental impacts. EAD then permits or rejects the project based on its environmental impacts. Once the project reaches its construction and operational phases, EAD reviews quarterly monitoring reports for relevant facilities and projects, with field inspectors ensuring facilities and projects comply with permit terms.

6.5 Outlook

The condition of Abu Dhabi Emirate's marine waters, as reflected by physical, chemical and biological characteristics, is generally very good. However, increasing trends in the concentrations of nutrients (nitrate, phosphate and chlorophyll-a) indicate that eutrophication is an ongoing threat to water quality in the emirate, as it is in many other nations around the world.

EAD has taken significant steps to curtail the continued elevation of nutrients, and the ongoing execution of regulations and limits will significantly help to abate this issue in the coming years. The implementation of ambient marine water quality limits will help improve and safeguard the health of the emirate's marine waters. Knowledge gleaned from EAD's comprehensive, world class marine water quality monitoring programme is central to the design and development of strategies for reducing eutrophication.

Future Responses

Although significant efforts have been made to manage and protect marine water quality in Abu Dhabi Emirate, EAD continuously plans and develops new initiatives to safeguard the marine environment. In-house capacity building in the field of marine water quality is essential to building and maintaining a strong, diverse team specialised in marine water quality, hydrodynamics and marine biology.

The development and refining of Marine Emergency Response Plans is essential. Further regulatory development, such as regulatory implementation of ambient limits and revised industrial effluent standards, is underway. Additionally, the sharing of marine water quality data through a unified portal with all stakeholders is under development with the UAE Ministry of Climate Change and Environment, which will effectively share knowledge and information among partners.

Lastly, educating the public on the status of marine water quality and related issues to increase their awareness will lend support to all Government of Abu Dhabi marine water quality initiatives. This is accomplished through awareness campaigns targeting communities at all levels. A collaboration with the Ministry of Education aims to inform the emirate's youth by disseminating key messages on the importance of protecting Abu Dhabi Emirate's rich marine water heritage.

In-house capacity building has been a key target for EAD, in order to build a specialised team of marine water experts

BIODIVERSITY

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KEY MESSAGES

DRIVERS

Population and economic growth are driving urban and industrial development, which are key causes of the degradation and loss of biodiversity.

PRESSURES

The pressures on the emirate's biodiversity are no different than in the rest of the world. Rapid industrial and urban development lead to habitat loss and degradation, further exacerbated by the effects of climate change in the emirate, with a significant impact on biodiversity. Over-exploitation of the emirate's fisheries has led to a collapse of fish stocks for some key species.

STATE

In spite of the harsh environment, the emirate's biodiversity is rich, with both regional and global significance. Abu Dhabi Emirate has nearly 3,800 known species and more are being discovered. Populations of some key species are stable, although many have declined. Of the total known species in the emirate, less than 2 % are classified as 'threatened'.

IMPACTS

In addition to the broader impact of habitat loss on biodiversity there is also a bleak outlook for the future of some species in the emirate, including the Arabian Tahr, Sooty Falcon and some commercially exploited fish species.

RESPONSES

An extensive network of Protected Areas (PAs) covers nearly 29 % of the emirate's terrestrial and marine biomes. Monitoring and reintroduction programmes are leading to a change in the status of some of the most threatened species. The development of policies, regulatory frameworks and other policy instruments (such as guidelines) is likely to bring more positive changes for the long-term conservation of the emirate's biodiversity.

7 Introduction

KEY INDICATOR OF CURRENT STATE: **80 %** OF TERRESTRIAL AND MARINE HABITAT BASELINE AREA RETAINED IN ABU DHABI IN 2015

Richness of Biodiversity

While relatively small in geographic terms, Abu Dhabi Emirate has a rich biodiversity. Considering that a sizeable portion of the emirate is desert with low species diversity [1], it is home to important species of invertebrates, plants, mammals, reptiles and birds, both in the terrestrial as well as marine realms. To date, 3,787 species of plants, invertebrates, higher vertebrates and fish have been documented in the emirate (Figure 7.1).

The Biodiversity Challenge

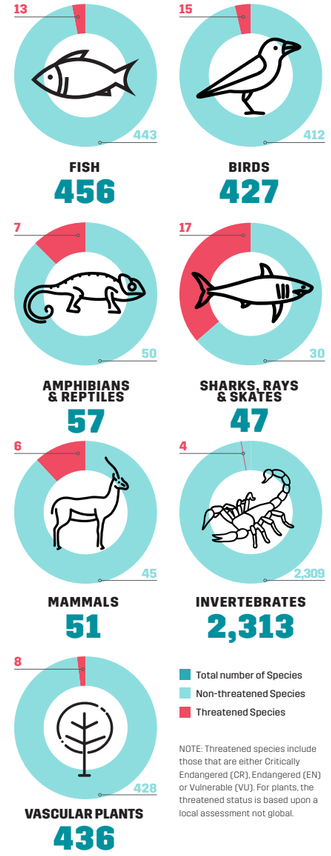
Although less than 2 % of all the species recorded in the emirate are classified as 'threatened' on the International Union for Conservation of Nature's (IUCN's) Red List, a much higher percentage could be considered 'vulnerable'. The emirate's species are threatened due to a multitude of factors, the main one being a loss of habitat due to rapid development along the coastline.

Conservation of biodiversity ranks high on the UAE National Agenda: it provides ecosystem services, creates a livelihood for local communities, and also has enormous socio-economic benefits through eco-tourism. Additionally, the aesthetic and intrinsic values of the emirate's biodiversity, alongside traditional practices such as falconry and pearl diving, are intricately linked to the local culture, finding resonance in conservation efforts for certain species and habitats.

The Global Policy Framework for Biodiversity

The Convention on Biological Diversity (CBD) is the single most important multi-lateral framework for the conservation of biodiversity. As an obligation to the Convention and in order to ensure its implementation, the recently developed National Biodiversity Strategy and Action Plan (NBSAP) is a mechanism to implement global commitment through local actions. The UAE is signatory to other multi-lateral agreements and MoUs, such as the Convention on International Trade

FIGURE 7.1 Known Marine and Terrestrial Species in Abu Dhabi Emirate



SOURCE: EAD, 2012 [2]. EAD, 2016 [3]

The UAE is a signatory to the MoU on the Conservation and Management of Marine Turtles and their Habitats

in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention, Cartagena Protocol on Biosafety, Nagoya Protocol, United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol, Regional Organisation for the Protection of the Marine Environment (ROPME), and United Nations Convention to Combat Desertification (UNCCD).

UAE is signatory to the MoU on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA), and is developing a National Plan of Action (NOPA) to further protect the species. It is also a signatory to the MoU on the Conservation and Management of Dugongs and their Habitats throughout their Range, and the MoU on the Conservation of Migratory Birds of Prey in Africa and Eurasia. Recently, the UAE signed the Convention on the Conservation of Migratory Species of Wild Animals (CMS), as a commitment to protecting globally threatened migratory species.

The Local Policy Framework for Biodiversity

The Abu Dhabi Plan is the key policy framework that set the agenda for the conservation of biodiversity in the emirate. Additionally, the Biodiversity Strategy for the Emirate of Abu Dhabi 2015-2020 is the policy framework which identifies initiatives for implementation from the five strategic priorities related to the emirate's biodiversity.

The objectives and targets of the Biodiversity Strategy are aligned to the National Biodiversity Strategy and Action Plan 2014-2021, which was developed by the Ministry of Climate Change and Environment (MOCCAE). The international conventions and other multi-lateral agreements to which UAE is signatory provide further input and guidance for conservation of the UAE's biodiversity. EAD works very closely with MOCCAE to meet policy, regulatory and implementation obligations for such conventions and treaties at both local and federal levels. EAD has strengthened the biodiversity regulatory framework through guidelines and the introduction of new permit requirements to better manage existing pressures and protect biodiversity. This includes the Hunting Law and permits for research activities, wildlife specimen collection and mangrove plantation projects. The development of policies and guidelines on habitat protection, protected areas, fisheries, integrated coastal zone management, wildlife conservation and grazing are planned over the next few years.

7.1 State

The emirate has a rich diversity of habitats within a relatively small and harsh arid environment. Twelve critical terrestrial and marine habitats have been identified in the emirate, along with many sub-habitats.

The diverse coastal habitats of Abu Dhabi Emirate are home to a large number of resident and migratory species. Many of the emirate's offshore islands are home to a large number of breeding terns and gulls, some of which are of national and regional importance [5]. The emirate is home to Marawah Marine Biosphere Reserve (MMBR), the first reserve of its type, under UNESCO's Man and Biosphere (MAB) network.

The emirate also has two Ramsar Sites (Al Wathba Wetland Reserve and Bul Syayeef), 14 Important Bird Areas (IBAs) [6], and one IOSEA Marine Turtle Site. Some of the emirate's offshore islands are an important breeding ground for endangered Hawksbill Turtles. Recognition of south-western Abu Dhabi's waters as Ecologically and Biologically Significant Marine Areas (EBSA) is an indicator of the importance of Abu Dhabi Emirate, both locally and internationally. Terrestrial and marine environments in the emirate support 3,331 known documented species of plants, invertebrates, reptiles, birds and mammals, and 456 species of fish (Figure 7.1). Invertebrate fauna is still poorly described; however, EAD recently discovered four species which are new to science [7, 8].

TABLE 7.1 Critical Habitats in Abu Dhabi Emirate

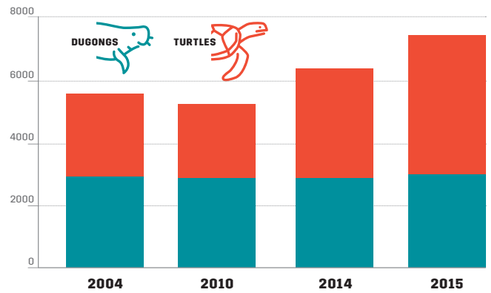
CRITICAL HABITATS	TOTAL AREA (KM^2)	REPRESENTATION IN PROPOSED, DECLARED OR ESTABLISH PROTECTED AREAS (%)
WADIS AND FLOODPLAINS	137.52	40.35
SAND SHEETS AND DUNES WITH TREE COVER	184.54	1.24
ALLUVIAL OR INTERDUNAL PLAINS WITH DWARF SHRUB COVER	811.53	37.52
MOUNTAINS (JEBAL HAFIT)	24.80	99.82
NORTHERN ALLUVIAL OR INTERDUNAL PLAIN	26.97	0.67
SAND SHEETS AND DUNES WITH DISTINCT SHRUB COVER OR DWARF SHRUB COVER	324.12	78.18
BURQAS AND MESAS	69.80	28.19
INTERTIDAL MUDFLATS	354.00	32.80
CORAL REEF	310.66	65.40
SEAGRASS	1,024.27	40.80
MANGROVES	155.20	8.90
SALTMARSH	47.86	19.45

SOURCE: EAD, 2015

The availability of nesting sites for bird species, such as the Little Green Bee-eater, are facing a variety of pressures

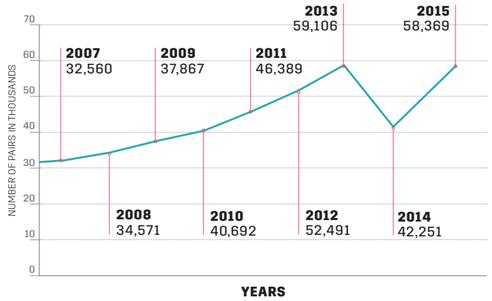
The UAE is home to the second-largest population of Dugongs (*Dugong dugon*) in the world, comprising nearly 3,000 individual animals. The species' population has been stable over the years thanks to improved management following the establishment of the Marawah Marine Biosphere Reserve and better monitoring and surveillance (Figure 7.2).

FIGURE 7.2 Status of Dugongs and Turtles in Abu Dhabi Waters Based on Winter Counts



SOURCE: EAD

FIGURE 7.3 Lesser Crested Tern Numbers in Abu Dhabi



SOURCE: EAD

The number of overall foraging marine turtles, namely Hawksbill (*Eretmochelys imbricata*) and Green (*Chelonia mydas*) Turtles, have been relatively stable over the last decade, based on data from aerial surveys. The number of nesting Hawksbill Turtles has remained stable.

Corals in the waters of Abu Dhabi Emirate have adapted to survive the hottest temperatures in the world [9]. They host an incredibly rare species of symbiotic algae, *Symbiodinium thermophilus*, and support its unique thermal tolerance [10]. Studies of the emirate's corals and fish are now being used to inform global science about how organisms respond to extreme temperatures and the potential impacts of climate change [11, 12].

Long-term monitoring of breeding birds has shown a stable population of some tern species in the emirate. Numbers of the Lesser Crested Tern (*Sterna bengalensis*) have increased steadily over the years due to improved protection at some of the privately owned islands (Figure 7.3).

Among plant species, *Schweinfurthia imbricata* is threatened, while the dwarf palm *Nannorrhops ritchieana* is listed as vulnerable by IUCN, and so far has been recorded in Jebal Hafit only. Other important species include the White Saxaul *Haloxylon persicum*, mangrove species *Avicennia marina* and succulents *Desmidorchis flavus* and *Desmidorchis arabicus*.

Threatened Species and Habitats

Less than 2 % of the known taxa (excluding invertebrates) is threatened as *per* the IUCN Red List (see Figure 7.1, a detailed list is available from www.scad.ae). However, at a local level, this percentage is not a true reflection of the threat to habitats and species. Unfortunately, the absence of a local Red List, other than for flora, limits our ability to understand and monitor species that are threatened locally. Although population trends of many species are still stable, some have shown decline, both in extent as well as population size. The population of Socotra Cormorant (*Phalacrocorax nigrogulatis*), a globally threatened species, has declined over the years, and the number of breeding colonies have been significantly reduced by nearly 50 % over the last decade. Stocks of commercially exploited fish species such as Hamour (*Epinephelus coioides*), Shaari (*Lethrinus nebulosus*) and Kanad (*Scomberomorus commerson*) have collapsed over the last few decades due to over-fishing (Chapter 9 – Fisheries).

The Arabian Oryx (*Oryx leucoryx*), which once roamed freely in the region, was considered extinct in the wild until a reintroduction programme established a new population in eastern Abu Dhabi. Numbers of other large mammals have also possibly declined, including the highly threatened Arabian Tahr (*Hemitragus jayakari*), which currently survives in much smaller numbers on Jebal Hafit.

Many terrestrial ecosystems are under various degrees of threat [13], with a number of different habitat types considered highly threatened because of a significant transformation from their original extent. Wadis and floodplains around the emirate are critically endangered, with only 19 % of the original area still in good condition. Areas identified as threatened include coastal plains, sand sheets, dunes, inter-dunal plains with dwarf shrub, coastal sabkhas and Jebal Hafit mountain. In the marine realm, corals, seagrass and saltmarshes are highly threatened.

Invasive and Pest Species

The emirate's species face threats from a variety of natural and anthropogenic factors. Although habitat loss is a major threat, invasive species also pose a formidable threat to many local species, largely due to their ability to rapidly colonise and displace native species. More than 147 known documented Invasive Alien Species (IAS) are present in terrestrial and freshwater environments [14]. Although as yet undocumented, Abu Dhabi Emirate's marine environment possibly has an even higher proportion of IAS, largely introduced through ballast waters. A high number of IAS can be detrimental to native species and has implications for the integrity, overall health and wellbeing of natural ecosystems [1]. MOCCAE recently concluded an exercise to create an inventory, prioritise and rank all known IAS in the UAE, an important first step towards developing control programmes and policy and regulatory frameworks. There are 39 non-native plant species reported in the UAE, of which five are invasive. Highly invasive alien species of plants, such as mesquite (*Prosopis juliflora*), have already colonised many areas in Abu Dhabi Emirate and can have significant impacts [15]. Among birds, eight species have been listed as invasive from over 125 non-native species reported in the UAE. Species such as the Indian Myna (*Acridotheres tristis*) and Indian House Crow (*Corvus splendens*) are well established and potentially detrimental to some local species as they compete with them for resources [16].

The Dugong population has stabilised due to better monitoring and conservation practices

Protected Areas

The emirate has a network of 19 protected areas (comprising six marine and 13 terrestrial) which contribute to achieving 2020 targets for terrestrial and marine protected areas. These areas support some of the best and most critical terrestrial and marine habitats, as well as significant species populations. Despite covering nearly 17,000 km^2 of land and sea, the current network of protected areas still requires further expansion in order to adequately represent the full range of key habitats within Abu Dhabi Emirate. There are also 540 afforested areas, covering a total of 242,000 ha, of which 104 were earmarked for decommission by the end of 2016. These forests cover 3.5 % of the emirate's total land area, have over 20 million trees and provide suitable shelter to over 55,000 gazelle and other ungulates from 14 different species. Although the impact of forests on natural resources, especially water, is well known, these green areas attract a large number of migratory bird species to rest and feed during their autumn and spring migrations and passage through the UAE.

7.2 Drivers & Pressures

Increasing Population and Pressure on Biodiversity

The population of Abu Dhabi Emirate has grown rapidly over the last few decades (see Chapter 2 – Driving Forces of Environmental Change). This rapid population growth, along with an increase in urbanisation and industrialisation, has put heavy pressure on the emirate's biodiversity. Habitat loss, alteration and fragmentation are major concerns, especially in coastal areas [17]. Development activities along the coast for residential, industrial and commercial purposes directly impact the availability of safe nesting beaches for turtles and suitable habitats for breeding birds and many other wildlife species. Development has also expanded inland, even in remote desert areas, causing fragmentation of habitat and isolation of species, which in turn may affect their existence. Pollution is another major pressure, which affects biodiversity in both direct and indirect ways. Terrestrial ecosystems can be polluted from multiple sources, such as toxic chemicals from industrial processes and waste in landfills, as well as littering and inconsiderate recreational activities. Marine ecosystems can be overloaded with pollutants from factories, desalination plants and marine transport [17]. Air pollutants emitted by transport and the industrial sector also have an impact on ecosystems and species. Although a source of air pollution may be located many kilometres away, its dispersal is uncontrollable.

A growing population and economy in the Emirate of Abu Dhabi is a threat to biodiversity and natural resources

Rapid economic growth and the illegal trade in animals have introduced many invasive species into the emirate. These IAS compete with the emirate's native species for natural resources, as well as negatively impacting species' breeding, which in turn may affect the natural environment.

Climate change impacts, such as rising temperatures and sea level, frequent extreme weather events and changing patterns of rainfall and drought, affect ecosystems and species' ability to adapt, consequently increasing biodiversity loss. Increasing positive seawater temperature anomalies have had a devastating impact on coral reefs in Abu Dhabi Emirate [18, 19, 20].

The emirate's dramatic growth in population, consumption and economic activities has led to resources being over-exploited, which is expected to threaten biodiversity and ecosystems and affect the ecological balance. Over-exploitation of the emirate's fisheries has led to a collapse of stocks for some key commercial fish species [21]. The illegal trade in exotic animals is a major threat to endangered species.

7.3 Impacts

Impacts on Biodiversity

Rapid population growth and associated industrial and urban development have caused a significant loss of habitat and resultant decline in populations of species [17]. Although long-term trend data from much of the emirate's terrestrial environment is not available, particularly on free-ranging species such as the Sand Cat (*Felis margarita*), Sand Gazelles (*Gazella subgutturosa*) and Mountain Gazelles (*Gazella gazella*), it is quite likely that many of these species have undergone declines in recent years.

Jebal Hafit, the only mountain habitat in the emirate, is not yet protected, despite having the only population of Arabian Tahr and Egyptian Vulture (*Neophron percnopterus*). Past and current development on and around the mountain further threatens these two iconic and globally threatened species, as well as other typical mountain dwelling species. The area also hosts one of the few known roosts of the Egyptian Fruit Bat (*Rousettus aegyptiacus*), which was almost lost to development before intervention and the implementation of protective measures to save the species.

Key fish stocks have collapsed as result of over-exploitation [21]. By 2015, the adult reproductive stock size for the three key demersal indicator species – Hamour, Shaari and Farsh – had fallen by over 90 % (see Chapter 9 – Fisheries for further details).

The proliferation and existence of a large number of IAS are also an indication of the alteration and deterioration of the emirate's natural environment. Pest species can be extremely harmful, particularly on offshore islands where many important species of seabirds breed. An infestation by the Norway Rat (*Rattus norwegicus*) on Abu Al Abyad Island in 2004 predated more than 50 % of all Crab Plover eggs, a species with only two known breeding sites in the UAE [22, 2]. The Indian House Crow has fast spread along the coast and is likely to move further westward with an increase in urban and industrial developments.

Jebal Hafit is home to a number of key native species, including the Arabian Tahr and Egyptian Fruit Bat

There is a significantly large roosting colony on the island of Delma and further spread of the species to some offshore islands could be detrimental to breeding seabirds.

IAS and other exotic species brought into the UAE environment not only pose disease risk to wild species but can have impact on human health as well. A strain of green algae, *Caulerpa sp.*, has been recorded from coastal waters and has the potential to replace native plants and deprive marine life of food and habitat.

Impacts of Climate Change on Biodiversity

Important feeding and nesting grounds of birds, as well as turtle nesting beaches, may potentially be lost with a rise in sea level. Corals in the UAE experience high temperatures and salinity due to the shallowness of the Gulf. Water temperatures of 35 to 37°C have been recorded at least five times since the late 1990s, particularly in 1996 and 1998, causing extensive coral bleaching and mortality [23]. Impacts of climate change are exacerbated by coastal development activities, which can cause direct habitat loss, or secondary impacts due to loss of illumination and sedimentation [24]. Other foreseeable impacts of climate change include changes in ranges, distribution patterns and possible decline in species diversity.

Species including the Mountain Gazelle use the emirate's forested areas for shelter

Marine ecosystems and fisheries in particular are being threatened by overfishing, but also by pollution and other anthropogenic causes [25]. Pollution and dredging are impacting marine water quality [17] resulting in algal blooms and fish kills.

The coastal and marine environment of Abu Dhabi Emirate comprises a number of diverse and interdependent habitats, including coastal wetlands largely dominated by mangroves, lagoons, coral reefs and seagrass beds. Physical alterations of the coastal zone have significantly impacted the coastal habitats and resources, leading to habitat degradation, fragmentation and loss. These include: land reclamation, grading, dredging, channelisation and coastal defence measures such as diking, armouring and the erection of beach stabilisation structures (breakwaters, groynes, sills), plus urbanisation.

Coastal landfill is particularly widespread in the emirate, and a significant portion of the shoreline is artificial. Habitat degradation tends to lower its ability to support biological communities, leading to a reduction in productivity. Fragmentation often leads to isolation of inter-dependent habitats, which in turn results in impaired functioning. At the same time, dunes and beaches are mined for sand or graded to make way for shore-front hotels, leisure facilities and residential developments. The destruction of these habitats not only manifests in the loss of biodiversity but also in the loss of valuable goods and services that these habitats provide, particularly with regards to coastline protection [26, 17].

Over-grazing has been a significant threat to natural desert vegetation over the past few decades, leading to the degradation of some of these areas. Grazing by camels and other livestock is a major issue and limits regeneration in overgrazed areas.

Climate change may adversely impact some key and charismatic species, such as nesting Hawksbill Turtles and breeding seabirds, due to a loss and reduction in breeding habitats caused by sea level rise.

Afforested areas, which provide refuge to over 55,000 animals (including Sand Gazelle), Mountain Gazelle and Arabian Oryx (*Oryx leucoryx*)) and numerous migratory and resident bird species, also put strain on groundwater supplies, one of the emirate's most precious natural resources. The use of groundwater for irrigating forested areas consumes 16 % of the available groundwater budget, the second-biggest consumer after the agricultural sector. Fast-depleting groundwater resources exacerbate aridity and affect the growth of natural vegetation.

Impacts on Culture, Traditions and Values

Unfortunately, impacts from development may also result in the loss of important natural heritage and related traditions, recreational opportunities, and intrinsic and aesthetic values. A loss of biodiversity may result in the loss of ecosystem services and bring vectors and pathogens that can affect human health.

Traditions and cultures often have symbiotic relationships and one cannot survive without the other. This is very true in Abu Dhabi Emirate, where local traditions of pearling and falconry have ensured sustained support and interest in biodiversity conservation. The over-exploitation and illegal poaching of falcons from their breeding areas for falconry may have long-term consequences on sustaining traditional falconry practices in the emirate.

7.4 Responses

Protecting Threatened Habitats and Species

Establishing a representative and well-managed network of marine and terrestrial protected areas is one of the strongest and most effective conservation measures taken to protect biodiversity from various threats. Six Marine Protected Areas and 13 Terrestrial Protected Areas containing critical habitats have been established. These represent the majority of important critical habitats in Abu Dhabi Emirate, reaching a target of 13.45 % marine and 15.43 % terrestrial area (see Map 7.1). An extensive emirate-wide habitat mapping project by EAD has resulted in the first-ever mapping of all terrestrial and marine habitats. This has been critical in understanding the extent of habitats available and the urgency with which they need to be protected, either formally within a protected area network or through other forms of protection.

As well as establishing effective protected areas, the emirate has also performed well in their management. The Management Effectiveness Tracking Tool (METT), IUCN's World Commission on Protected Areas (WCPA) framework, showed an increase from 63 % to 84 % in two years (2014-2015), compared to the world average of 53 % (see Figure 7.4).

The emirate has a very strong ex-situ conservation programme. Large collections of animals, a legacy of the late Sheikh Zayed bin Sultan Al Nahyan, have been established over the years. These animals, some of which are highly threatened, are assets for both local and global conservation programmes.

The iconic Arabian Oryx, once extinct in the wild, has been brought back to the emirate through a

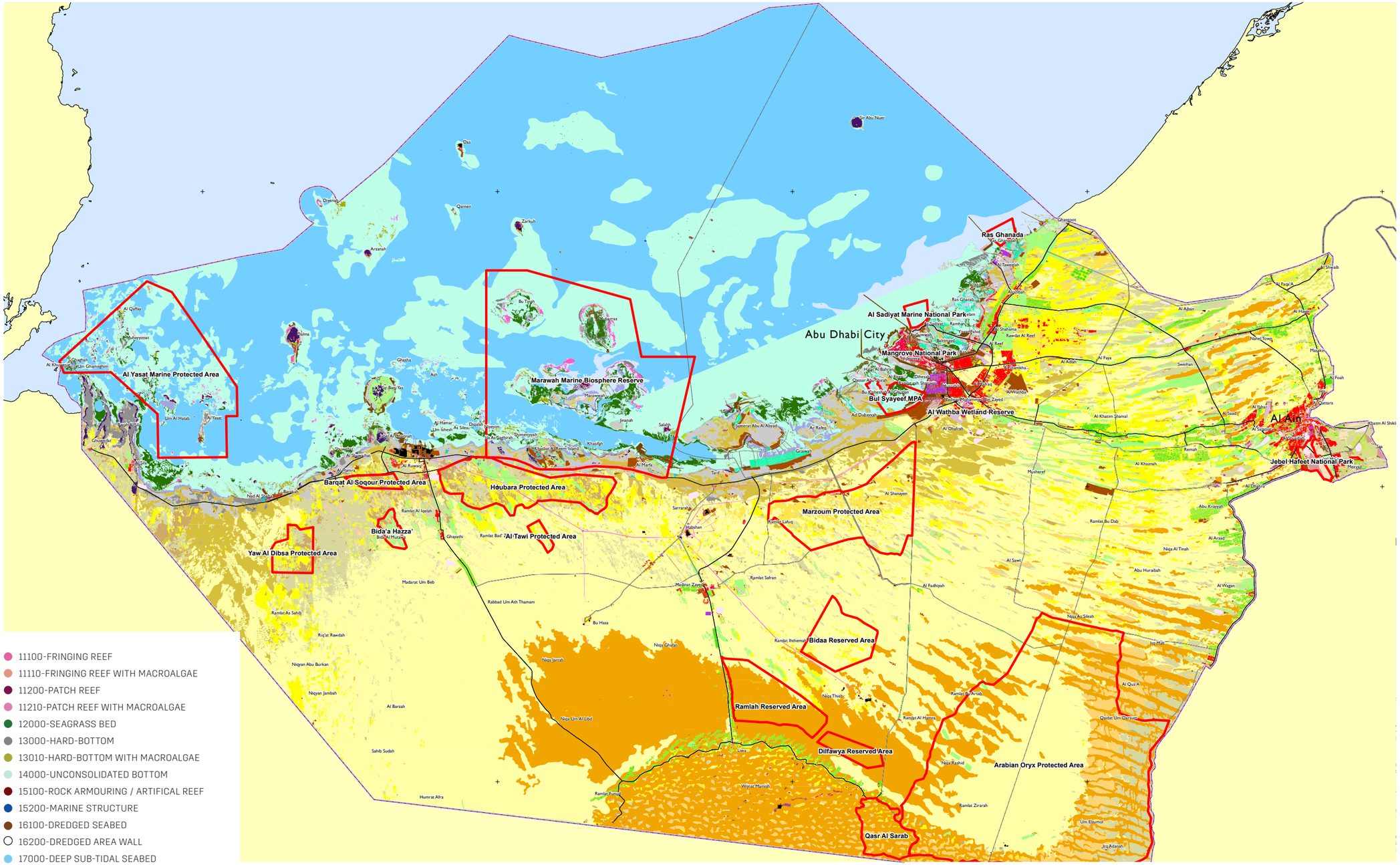
Scimitar-horned Oryx are tagged at the Deleika Wildlife Conservation Centre, as part of EAD's pioneering reintroduction programme

MAP 7.1 Terrestrial and Marine Protected Areas within Abu Dhabi Emirate

- 1010-MUDFLATS AND SAND EXPOSED
- 1020-SHELTERED TIDAL FLATS WITH CYANOBACTERIAL MATS
- 1030-SALTMARSH
- 1040-MANGROVES
- 1050-STORM BEACH RIDGES
- 1060-SANDY BEACHES
- 1070-BEACH ROCK AND GRAVELLY BEACHES
- 2011-COASTAL PLAINS ON WELL-DRAINED SANDY GROUND
- 1060-SANDY BEACHES
- 2020-COASTAL SAND SHEETS AND LOW DUNES
- 2030-COASTAL CLIFFS, HEADLANDS, ROCKY SLOPES AND WADIS IN COASTAL SITUATIONS
- 3100-COASTAL SABKHA, INCLUDING SABKHA MATTI
- 4110-SAND SHEETS AND DUNES WITH TREE COVER
- 4120-SAND SHEETS AND DUNES WITH SHRUB COVER
- 4130-SAND SHEETS AND DUNES WITH DWARF SHRUB COVER
- 4140-SAND SHEETS AND DUNES WITH PERENNIAL HERBS AND GRAMINOIDS
- 4200-MEGA-DUNES
- 5110-GRAVEL PLAINS WITH DISTINCT TREE VEGETATION
- 5120-GRAVEL PLAINS WITH DWARF SHRUB VEGETATION
- 5130-GRAVEL PLAINS WITH SPARSE VEGETATION
- 5200-INLAND SABKHA
- 6100-MOUNTAIN SLOPES, SCREE AND ASSOCIATED WADIS
- 6210-JEBELS (INCLUDING MESAS AND BURQAS)
- 6220-ESCARPMENTS, LITHIFIED SAND DUNES, ROCKY EXPOSURES
- 6320-WADIS IN OPEN TERRAIN, AND DRAINAGE CHANNELS
- 7100-SEMI-ARTIFICIAL LAKES
- 7200-MOIST GROUND WITH PHRAGMITES, TAMARIX AND GRASS MATS
- 8100-DATE PLANTATIONS
- 8200-FARMLAND
- 8300-LIVESTOCK AREAS
- 8400-FORESTRY PLANTATIONS
- 9110-HIGH DENSITY URBAN
- 9120-LOW DENSITY URBAN
- 9210-OIL INDUSTRY
- 9220-AIRPORTS AND AERODROMES
- 9230-PORT AREAS
- 9240-OTHER INDUSTRY
- 9300-LEISURE AREAS
- 9400-PAVED ROADS
- 9500-PIPELINES INFRASTRUCTURE
- 9600-DISTURBED GROUND

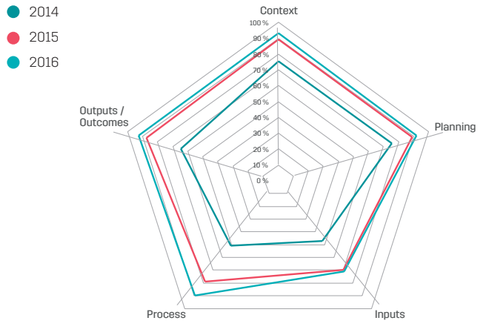
- 11100-FRINGING REEF
- 11110-FRINGING REEF WITH MACROALGAE
- 11200-PATCH REEF
- 11210-PATCH REEF WITH MACROALGAE
- 12000-SEAGRASS BED
- 13000-HARD-BOTTOM
- 13010-HARD-BOTTOM WITH MACROALGAE
- 14000-UNCONSOLIDATED BOTTOM
- 15100-ROCK ARMOURING / ARTIFICAL REEF
- 15200-MARINE STRUCTURE
- 16100-DREDGED SEABED
- 16200-DREDGED AREA WALL
- 17000-DEEP SUB-TIDAL SEABED

SOURCE: EAD



EAD has led a ground-breaking programme to reintroduce Scimitar-horned Oryx into Chad

FIGURE 7.4 Effectiveness of Abu Dhabi PAs



SOURCE: EAD

reintroduction initiative using collections in the ex-situ programme. Their population in the Arabian Oryx Protected Area currently stands at over 400 animals, and the species' status was down-listed from 'endangered' to 'vulnerable' in 2011 [27].

A release of Arabian Oryx is also planned for the Qasr Al Sarab Protected Area. The establishment of World Herds for other threatened species is EAD's response and commitment to protecting threatened species, not just locally but also regionally and globally. Over the last few years, 100 Nubian Ibex and 60 Arabian Oryx have been successfully reintroduced into Jordan. The largest and first-ever reintroduction of the Scimitar-horned Oryx was undertaken during 2016, with two groups of animals already released in the Ouadi Rime-Ouadi Achim Game Reserve in Chad. By bringing back a species that became extinct in the wild 15 years previously, this achievement is a major global conservation milestone. Extensive and pioneering ecological research on the threatened Houbara (previously under the National Avian Research Center), has led to a better understanding on the ecology of the species across its range states [28, 29, 30].

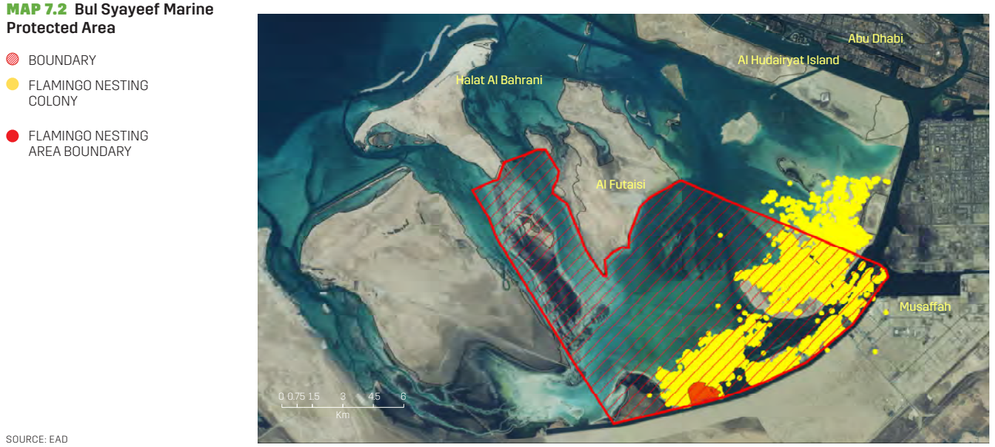
EAD's native plant nursery hosts over 75 local species, and is a key initiative to protect important and threatened species for the future restoration of degraded habitats. The plantation of 2 million mangroves has also been a major restoration effort, leading to a significant change in the extent of mangrove cover by 2016.

Programmes on Important and Threatened Species

Long-term research and monitoring programmes to collect data on key species and habitats are also in place. Such data is fundamental to EAD's understanding of trends and the corrective actions needed to respond to threats or adverse trends. Monitoring programmes on key species such as Dugongs, turtles, dolphins, seabirds and terrestrial mammals, have provided important information on their numbers and population trends and have helped identify important areas for many of these species. This has resulted in proposals for important sites either as protected areas or important conservation areas, such as Important Bird Areas (IBAs), Ecologically and Biologically Significant Marine Areas (EBSAs), Important Turtle Areas (ITAs) or Ramsar Sites. More examples include the establishment of Bul Syayeef as a marine protected area, the declaration of Al Wathba as a Ramsar Site, the identification of five new IBAs [5], and the classification of Abu Dhabi Emirate's western waters as EBSA.

In 2015, EAD and MOCCAE established the strategic UAE Sustainable Fisheries Programme in response to dwindling fish stocks. The programme aims to have at least 70 % of fisheries resources sustainably harvested above the 30 % threshold by 2021.

MAP 7.2 Bul Syayeef Marine Protected Area



SOURCE: EAD

Use of the latest tools and technologies has been extensive in EAD's assessment, monitoring and mapping of biodiversity in Abu Dhabi Emirate. Satellite tracking, geo-location and GSM technologies have been used to understand the movement and migration of Dugongs, turtles and many bird species. The use of remote cameras for key mammal species has helped document elusive species, such as sand cats, after a gap of many years in western Abu Dhabi.

The use of satellite tracking has revealed important ecological information for critically endangered species, such as the Hawksbill Turtle. Mobile-based data collection has been implemented for the majority of monitoring programmes, allowing seamless integration of field data into EAD's Environmental Database.

Monitoring programmes are essential for understanding and protecting key species in the emirate

In 2013, EAD introduced drones to count breeding birds and they are now used regularly for more efficient and accurate biodiversity monitoring, along with aerial surveys to monitor threatened species.

National and International Actions

The Emirate of Abu Dhabi supports a wide range of biodiversity conservation-related initiatives and programmes at both regional and international levels. Examples include the hosting and support of the Arabian Oryx Secretariat, reintroduction of Arabian Oryx and Nubian Ibex, and a partnership with the Government of Chad for the reintroduction of the Scimitar-horned Oryx. Additionally, the emirate supports and hosts MoUs on Dugongs, turtles and migratory birds of prey, and has hosted and funded the CMS Office and its programmes since 2008.

Abu Dhabi Global Environmental Data Initiative's (AGEDI) Blue Carbon Programme aims to understand the impact of climate change and develop a framework to further protect habitats as well as develop local capacity. The programme acts as a benchmark for regional and international initiatives for future climate change adaptation and further supports sub-national reporting towards national targets within the CBD.

Future Responses

In order to achieve its vision, 'Towards a sustainable environment for a sustainable future', EAD developed

The Dwarf Palm, one of the rarest plants in the Emirate of Abu Dhabi, grows in Jebel Hafit

a comprehensive strategy aligned to the Abu Dhabi Plan and the UAE's National Biodiversity Strategy and Action Plan 2014-2021. This will help to improve the status of biodiversity by mainstreaming and integrating terrestrial and marine biodiversity conservation needs with relevant emirate- and country-wide development plans.

To support this, a comprehensive understanding of biodiversity status will be achieved through the establishment and implementation of a biodiversity assessment and monitoring framework. In turn, this will enable informed and effective decision-making. The framework will include programmes to fill the gaps in understanding of biodiversity and develop and implement conservation plans for important or threatened species and critical habitats. Wider community participation is essential for biodiversity conservation and a 'citizen science' approach is at the core of this.

The Emirate of Abu Dhabi aims to build an effective and best-in-class legislative and regulatory framework for the environment by updating relevant biodiversity laws and regulations and working with local partners to ensure existing laws are effectively enforced. Development of policies on grazing and invasive species is an immediate priority, and both are expected to be created within the next two years.

Cooperation with key stakeholders is critical for achieving success, and EAD is working closely with federal/local governments and civil society entities to implement local, national, regional and international agreements and biodiversity-related plans. This will include the development and implementation of management plans to control pathways of selected IAS, and conducting collaborative research programmes to support continued improvement in the conservation of species, habitats and ecosystems. Furthermore, EAD plans to increase the involvement of the community in terrestrial and marine protected areas management.

Given the pervasive impacts of climate change on biodiversity, the Emirate of Abu Dhabi will mitigate and adapt to these by liaising with stakeholders to drive collective action and ensure adaptive management to protect Abu Dhabi Emirate's ecosystems and environmentally-valued land. Central to this, and in order to provide a scientific basis to inform decision-making, it will build comprehensive understanding and knowledge about climate change and its impacts.

In-situ conservation will be enhanced with a strong planning and legislative framework to set up and effectively manage representative networks of terrestrial and marine protected areas. Ex-situ conservation efforts to maintain sustainable populations of key flora and fauna will involve the development of excellent animal breeding facilities, plant nurseries and development of a gene bank, for rehabilitation of threatened species and degraded habitats.

7.5 Outlook

Transforming Information into Action

The relatively rich biodiversity of Abu Dhabi Emirate has never been as vulnerable as in the last few years. Recent conservation initiatives have provided useful information on the status of the emirate's biodiversity and habitats. However, the time has come to revisit initiatives and existing responses, given that developmental pressures are exacerbated by such impacts as climate change. Therefore, it is imperative to chart new roadmaps for conservation.

Sustainable development plans are essential for protecting the future of the emirate's biodiversity

The future of biodiversity in the emirate depends on the adequacy of the responses and choices made concerning development. The need to move quickly and more decisively is clear, in order to counter immediate threats and pressures. The last two decades of biodiversity monitoring have provided important and valuable data sets which should allow for more action-oriented programmes to be developed. The existing data on the emirate's wildlife should lead to the development of a local Red List, an essential first step in prioritising monitoring efforts, which will also fill in the spatial and temporal data gaps for key species. The local Red List for species is planned for completion by 2017, while a Red List of ecosystems should also be developed, possibly concomitantly.

The development and effective, immediate implementation of conservation action plans for threatened species remain a priority. Also, it is critical to develop management plans for key IAS, linking such data to other aspects of the environment to understand processes which are vital for the conservation of ecosystems.

Some assessment of the economic valuation of ecosystems is also imperative, as it may be an effective currency against developments that are detrimental to conservation.

EAD has made substantial progress in establishing a network of a representative PA system and meeting global targets. However, ensuring representativeness and including other critical habitats, such as sabkhas and tidal mudflats, within the PA network will certainly enhance the ability of these areas to protect and support a much wider range of habitats and species, leading towards attaining the target for habitat protection, which is more than 80 % of the 2014 baseline retained. Abu Dhabi Emirate ranks highly on PA management effectiveness for protected areas.

Sustainable Development

New development initiatives such as The Plan Gharbia (2030) for the Al Dhafra Region (which accounts for

CLIMATE CHANGE

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nearly 83 % of the emirate's landmass, generating over 40 % of the GDP of over AED 115 billion annually from its industries), will be a major driver of growth in a region which is the most biologically diverse in the emirate, and home to some of the most charismatic species of mammals, reptiles and birds. Responsible, sustainable development that has the environment at its core is critical to ensuring that the region not only generates almost half of the emirate's GDP but also protects the bulk of the emirate's biodiversity.

Improved Policy and Regulatory Framework

The ongoing conservation of Abu Dhabi Emirate's biodiversity requires revisions to the policy and regulatory framework in order to address emerging issues and challenges. In this context, creating more awareness on biodiversity and using innovative technologies to provide solutions to biodiversity challenges are fundamental.

Recognising that biodiversity is impacted by multiple sectors, EAD envisages major improvements in biodiversity conservation using Integrated Coastal Zone Management as a policy and planning process. This is imperative, particularly for coastal and marine biodiversity, which is associated with numerous economic, social, cultural and recreational activities. The mangrove guidelines and guidelines on habitats are steps in the right direction. However, there is an urgent need to develop policies on IAS and more effective mechanisms to control and manage infectious animal diseases through the stringent implementation of international laws, such as CITES.

Abu Dhabi Emirate is a signatory to the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)

KEY MESSAGES

DRIVERS

Rapid growth in demographic, social and economic development and the ever-increasing demand for water and energy are the main drivers for the increasing pressure exerted by greenhouse gas (GHG) emissions. The principal source of GHGs in Abu Dhabi Emirate is the combustion of fossil fuels by the energy and transportation sectors.

PRESSURES

The current pressures of climate change are shifting. Earlier concerns of ozone-depleting substances have diminished due to effective regulatory controls and awareness. However, there are new concerns about GHG emissions from power and fuel production, road transport, metal production and other manufacturing, and waste disposal sectors.

STATE

The Emirate of Abu Dhabi is already experiencing the effects of climate change, including increases in air and sea temperatures, sea level rise, higher acidity and salinity of marine water, and reduced rainfall.

IMPACTS

The emirate is particularly vulnerable to the impacts of climate change. This is due to the extreme arid climate and low-lying coastal areas, which are home to the majority of people and economic activity. Impacts include increased storm surges and erosion, which affect coastal development and coastal nesting species such as turtles, as well as habitat loss and die-off, such as coral bleaching.

RESPONSES

Abu Dhabi Emirate's existing plans and proposed strategies for sustainable development will achieve a reduction in the rate of GHG emissions in the mid-term against a business-as-usual scenario. The Abu Dhabi Government is committed to the implementation of the Intended Nationally Determined Contributions (INDCs) through economic diversification, which will yield mitigation and adaptation co-benefits.

8 Introduction

KEY INDICATOR OF CURRENT STATE: **40.55 TONNES/CAPITA CO_2** (BASED ON MID-YEAR REVISED 2012 POPULATION ESTIMATES PROVIDED BY SCAD)

The Climate Change Challenge

Climate is usually defined as the 'average weather' in a place over a period of time, ranging from months to thousands or millions of years. The classical period is 30 years. Climate includes patterns of temperature, precipitation, humidity, wind and seasons. Climate patterns play a fundamental role in shaping natural ecosystems as well as the human economies and cultures that depend on them. Climate change manifests itself in a variety of ways, including changes in temperature, rainfall and sea level, in addition to natural climate variability observed over comparable time periods.

Global studies indicate that the climate is changing more rapidly now than at any time in the recent past, with disruptive impacts. Analysis of Antarctic ice cores shows us that the concentration of carbon dioxide (CO_2) was stable over the last millennium until the early 19th century. It then started to rise, with concentrations now nearly 40 % higher than before the Industrial Revolution. Other measurements (e.g. isotopic data) confirm that the increase must be due to emissions of CO_2 from fossil fuel usage and deforestation. Measurements from older ice cores confirm that both the magnitude and rate of the recent increase are almost certainly unprecedented over the last 800,000 years [1].

Globally, the impacts of climate change are already being observed

The growth in industry in Abu Dhabi Emirate has led to a rise in GHG emissions

Because so many systems are tied to climate, changes can affect many related aspects of where and how people, plants and animals live. Those effects include food production and availability, the use of water and various health risks [2].

The Global Policy Framework for Climate Action

In 1992, many countries joined the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty that provides the framework for international cooperation on combatting climate change by limiting average global temperature increases and coping with its impacts.

By 1995, countries under the UNFCCC launched negotiations to strengthen the global response to climate change and, two years later, adopted the Kyoto Protocol.

In 2015, the Paris Agreement marked the latest step in the evolution of the UN climate change regime, charting a new course for global efforts against climate change. It provides a framework for climate action post-2020, after the second commitment period of the Kyoto Protocol ends. It was entered into force in 2016 at a record-breaking pace. The UAE ratified the Agreement on 21st September 2016, becoming the first in the GCC to do so. As of February 2017, 132 out of 197 parties have ratified the Paris Agreement. Under this new framework, signatories have pledged to take action to maintain global temperatures at less than 2°C above pre-industrial levels. Signatories should also prepare, communicate and maintain Nationally Determined Contributions (NDCs) that they intend to achieve, which are measured through a global stocktake every five years from 2020 and become progressively more ambitious [3]. Currently the NDCs submitted are insufficient to meet the goals of the Paris Agreement as they will lead to a 2.7°C rise in global temperatures. However, the terms of the Agreement include a ratchet mechanism to scale up ambitions with the aim of closing this gap. The UAE will also need to submit GHG mitigation and adaptation contributions, which will have a knock-on effect on the country's own local policy work, making it important to ensure timelines are set in advance of these global stocktakes.

The Local Policy Framework for Climate Action

At a federal level, UAE Vision 2021 recognises climate change as one of humanity's greatest challenges and states the country's commitment to developing and implementing innovative solutions for reducing its carbon footprint. Launched in 2010, it focuses on improving the quality of air, preserving water resources, increasing the contribution of clean energy and implementing green growth plans [4]. It has set a target for the share of clean energy contribution to the total energy to be 27 % by 2021.

In 2016, the UAE Government placed climate action higher in the political agenda with the creation of the Ministry of Climate Change and Environment (MOCCAE) during a cabinet reshuffle and the development of a National Climate Change Plan under the auspices of the new ministry.

At a local level, the Emirate of Abu Dhabi developed a Climate Change Strategy that was incorporated into the Abu Dhabi Plan.

8.1 State

Atmospheric GHG Concentrations

The largest contribution to global warming comes from the increase in atmospheric concentrations of CO_2 since the 1870s due to industrialisation. Concentrations of CO_2 in the atmosphere are higher now than at any time during the past 650,000 years. In the Northern Hemisphere, during the spring of 2015, the three-month global average concentration of CO_2 crossed the 400 parts *per* million (ppm) level for the first time [5]. Figure 8.1 shows global atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Atmospheric Temperature

Abu Dhabi Emirate is already experiencing climate change, with higher temperatures and lower precipitation levels.

The transportation sector is one of the biggest contributors of GHG in the atmosphere

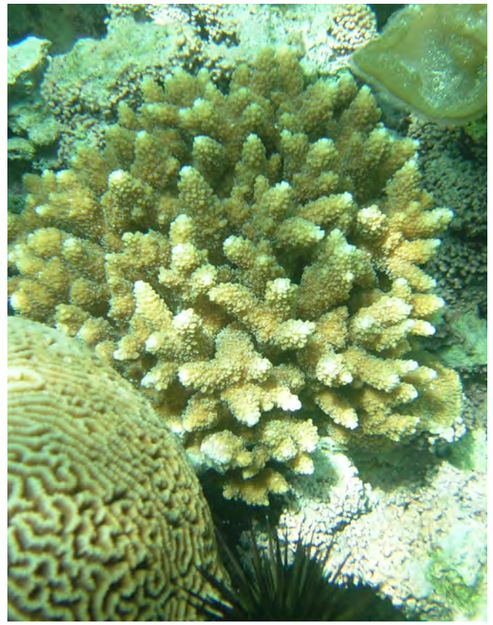
Sea surface temperatures in the Arabian Gulf have risen on average by 0.2°C *per* decade over the past 50 years, accelerating to 0.45°C *per* decade in the past 20 years [6]. In parts of the Gulf this rise has exceeded 0.6°C *per* decade, which is three times higher than the global average [7].

Rainfall

Lower precipitation levels were noticed in Abu Dhabi Emirate between 1982 and 2013, with a decrease in precipitation of 80 mm during that period [6]. Climate change may result in higher frequency and intensity of storm events, such as those recently observed in March 2015 and Hurricane Gonu in 2007.

Sea Level

Measurements from tide gauges in the region have

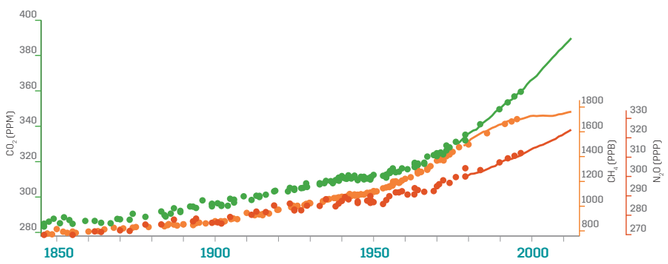


Climate change also has an impact on marine water quality, with Gulf waters becoming more acidic

confirmed that the level of the Arabian Gulf has been steadily rising [5]. Researchers found evidence of relative sea level rise of 2.2 mm (± 0.5 mm) *per* year between 1979 and 2007 [8]. During one well-defined winter shamal event in 2004, storm surges were recorded of 10 to 20 cm in the eastern half of the Arabian Gulf, and 20 to 30 cm in the coastal shallows of the UAE [9]. The increasing occurrence of El Niño, which is the warming of sea surface temperature (SST), presents a climate phenomenon that affects regular wind patterns in the Gulf [10].

Accurate prediction of future sea level rise is essential for planning. The Greenland and Antarctic ice sheets, which will potentially raise sea levels nearly 70 metres if completely melted, dominate uncertainties in projected sea-level change. Interpreting past changes in the sea and projecting future changes require sophisticated numerical modelling using coupled ice-atmosphere-ocean general circulation models. While substantial advances have been made, these models currently poorly represent the complex interactions between the atmosphere, the cryosphere and the ocean environment. The Sea-Ice Model Intercomparison Project (SIMIP) aims to better understand how sea ice works and evolves in the coupled climate system of the planet. The results of SIMIP will be incorporated into the next IPCC Assessment Report, AR6, expected to be released by 2021.

FIGURE 8.1 Global Average Greenhouse Gas Concentrations



SOURCE: IPCC 2014 [16]

Marine Water Quality

Chapter 6 looks at Marine Water Quality in more detail. However, climate change contributes to the quality of the marine environment, in addition to many other factors.

Already, the Arabian Gulf is becoming more acidic at a faster rate than most other oceanic waters around the world and this is likely to increase in the future [11]. Coral communities generally show a decrease in diversity with increasing salinity from east to west in Abu Dhabi Emirate [12, 13, 14].

The Emirate's marine biodiversity is impacted by a variety of stressors such as urbanisation, over-exploitation, habitat fragmentation and pollution, all of which reduce resilience [15]. Climate change acts synergistically with these factors and exerts additional pressures on biodiversity, reducing the ability to deliver critical goods and services.

8.2 Drivers & Pressures

Drivers of Climate Change

The Climate Report [11], which examined the causes and consequences of climate change, concluded that human activity is contributing to climate change by increasing the concentration in the atmosphere of GHG emissions.

Climate economists acknowledge that the main driving forces of GHG emissions are demographic change, social and economic development, as well as the rate and direction of technological change (see Chapter 2 – Driving Forces of Environmental Change for details).

Although the GHG emissions of Abu Dhabi Emirate do not exceed 0.26 % of the world total [17], they are expected to keep growing due to the following drivers [18]:

Population

Rapid economic growth driven by the discovery of oil in the 1960s has resulted in an unprecedented population boom in the UAE. This is due to high birth rates among UAE nationals, and as a consequence of immigrating expatriates seeking work in the expanding economy. In just two decades the population has doubled (see Chapter 2 – Driving Forces of Environmental Change).

The Government of Abu Dhabi predicts two more decades of rapid population growth. If it continues at the pace expected, the emirate's overall resident population would grow to more than 4 million by 2030. Although this population growth will undoubtedly bring economic benefits to the emirate and its citizens, it may also put a strain on the already fragile environment, because of the growing demand for energy, water and mobility, the main sources of CO_2 emissions.

Affluence

GDP growth is tightly correlated with energy consumption since goods and services in an economy are produced using energy and water. In Abu Dhabi Emirate there is a strong link between water and energy, since potable water is produced through the desalination of sea water. This energy-intensive process uses fossil fuels, mainly natural gas, and releases GHG emissions into the atmosphere, contributing to global warming. The emirate's reliance on desalinated water has resulted in very high energy and water consumption levels compared to global averages. According to SCAD's statistical data [19] from the period 2005 to 2015, the total electric power generated in Abu Dhabi Emirate in 2012 was approximately 66,626 GWH, an increase of around 162 % since 2005. The emirate's production of desalinated water was about 1,170.5 MCM in 2015, an increase of 57.6 % from 2005.

Technology

Between 1990 and 2006, the energy intensity of

TABLE 8.1 GHG Emissions in Abu Dhabi Emirate, 2012

	CO_2	CH_4	N_2O	PFCS	HFCS	SF6
GAS QUANTITY (GG)	93,875	573.19	3.91	1.0926 (CF_4) 0.1092 (C_2F_6)	0.0118	0.001
GLOBAL WARMING POTENTIAL (IPCC-SAR)	1	21	310	6,500 (CF_4) 9,200 (C_2F_6)	4,750	23,900
GAS QUANTITY (GG-EQUIVALENT)	93,875	12,037	1,213	8,107.231	56	1
GAS CONTRIBUTION (%)	81.4 %	10.4 %	1.1 %		7.1 %	

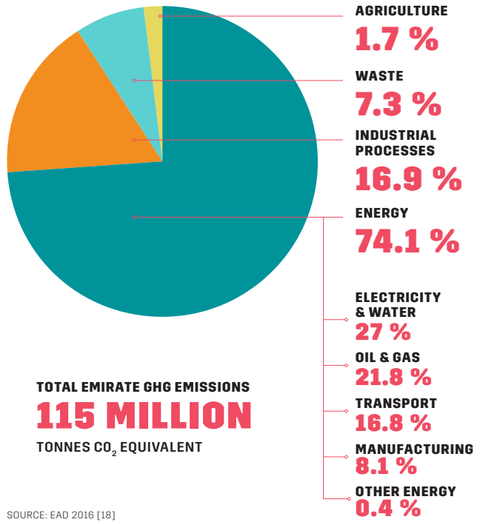
SOURCE: EAD [18]

TABLE 8.2 Carbon Sequestration by Vegetation

PLANTATION TYPE	CARBON SEQUESTRATION (MILLION TONNES CO_2)
FOREST LAND	4.097
WETLANDS (MANGROVES)	0.911
PERENNIALS CROPLAND	0.706
TOTAL	**5.714**

SOURCE: EAD [22]

FIGURE 8.2 Sources of GHG Emissions, 2012



SOURCE: EAD 2016 [18]

Abu Dhabi Emirate's economy has decreased, reflecting the diversification of revenue sources perceptible since the year 2000. The emirate's carbon intensity has remained constant, as there have not been significant changes in the technological mix of the energy supply system [20]. This situation is expected to change due to shifts in the structure of the economy and the diversification of the emirate's energy mix, which may affect carbon emissions.

To address its growing energy needs, Abu Dhabi Emirate is embarking on an ambitious programme to increase the reliance on renewable and low-carbon energy for power generation and, in the long term, for water desalination. Under this new scenario, carbon intensity will decrease although fossil fuel will still remain the main source of energy for transport and industry, as well as the main export commodity.

Pressures

GHG Emissions

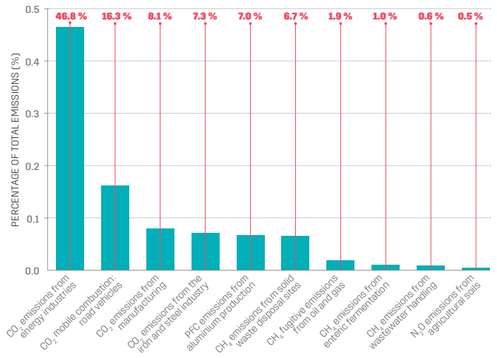
Anthropogenic GHG emissions in Abu Dhabi Emirate have been driven largely by economic and population growth. The emirate's GHG baseline (2010) and update (2012) inventories [21, 18] have shown that total direct GHG emissions increased from 99.1 million tonne CO_2-eq in the year 2010 to 115.3 million tonne CO_2-eq in 2012. This increase of 16.3 % over the two years was in line with the increased trend of the emirate's population (15.4 %) and GDP (15.5 %, in constant 2007 prices). Across the different source activities (energy, industrial processes, agriculture, land-use change and forestry (LUCF) and waste) the energy sector was the dominant contributor (of 74.1 %) of the emirate's GHG emissions in 2012. At a local level, the UAE aims to ensure sustainable development while preserving the environment, and to achieve a perfect balance between economic and social development.

Considering the amount of emitted GHG gases in the emirate and their global warming potential (according to IPCC Second Assessment Report), CO_2 was the major gas mainly emitted from fuel combustion, constituting 81.4 % of the total GHG emissions. Other GHG gases such as methane (CH_4), nitrous oxide (N_2O) and the F-gases (PFCs, HFCs, SF6) contributed less: 10.4 %, 1.1 %, and 7.1 %, respectively.

In 2012, approximately 5.7 million tonnes of CO_2 emissions (6 % of the emirate's total CO_2 emissions) were sequestered by the extensive system of forestry, perennial croplands and mangrove plantations throughout the emirate.

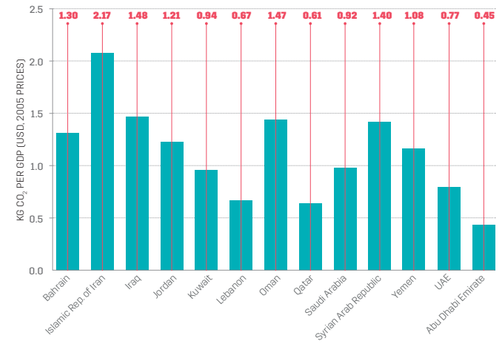
According to the IPCC supplement for wetlands [22], the added value of Abu Dhabi Emirate's wetlands (mangroves and seagrass meadows) is holding about 62 million tonnes of CO_2, where carbon is stored in the soil and biomass of the plants. This quantity may be released if the wetlands are extracted or drained. The key category analysis of GHG emissions in the emirate showed that the CO_2 emissions attributed to stationary fuel combustion for energy industries (oil, gas and power, combined with water desalination) and mobile fuel combustion in road vehicles require particular attention in mitigation plans (Figure 8.3). Abu Dhabi's contribution to global GHG emissions is quite small in comparison to other developing communities. However, the *per capita* CO_2 emissions from fuel combustion were among the highest in the region, reaching 34.4 tonnes CO_2/capita in 2012, an increase of 5.6 % from 2010.

FIGURE 8.3 Key Category Analysis of GHG Emissions in Abu Dhabi Emirate



SOURCE: EAD 2016 [18]

FIGURE 8.4 Emission Indicators (CO_2 from fuel combustion *per* GDP and *per* kWh) for Abu Dhabi Emirate and Other Countries in the Middle East, 2012



SOURCE: EAD 2016 [18], IEA 2014 [24]

While the CO_2 emissions from fuel combustion *per* GDP indicator increased to 0.45 kg CO_2/USD in 2012 (an increase of 6.6 % over 2010), the carbon intensity for electricity production decreased to 0.42 kg CO_2/kWh (a reduction of 10.6 % from 2010). This reflects the switch to a cleaner fossil fuel (natural gas) for electricity and water production in the year 2012. However, the main player in emission indicators is CO_2, with levels increasing faster than both population and GDP between 2010 and 2012. The main activities contributing to 2012's CO_2 emissions were the production of public electricity and water desalination (which contributed to 33 % of all CO_2 emissions), oil and gas extraction and processing (25 %), manufacturing and industrial processes (22 %) and transport (20 %). The above categories are therefore key for future improvement in the emirate's emission indicators.

Compared with neighbouring countries in the GCC, Abu Dhabi Emirate's emission indicators linked to the economy or electricity production were low (Figure 8.4). This reflects the effective performance of economic development with low emission intensities in Abu Dhabi Emirate, and the use of efficient technology and clean fuel compared to other countries in the region.

It should be noted that no single indicator can provide a complete picture of a country's CO_2 emissions performance or its relative capacity to reduce emissions [23].

Figure 8.2 helps to identify how best to respond.

8.3 Impacts

Sea Level Rise and Coastal Vulnerability

In a world affected by climate change, stronger than normal winds in the Arabian Gulf region (known as 'shamal systems') could be strengthened, amplifying the impact of sea level rise through storm surges on cities in the UAE [25]. Such increased frequency and amplitude may also impact the ability of the offshore oil and gas sector to operate by increasing the number of down days. Shamal systems, in combination with climatic changes in atmospheric pressure, sea surface temperature, coastal topography and tidal effects, could result in higher peaks of storm surges in Abu Dhabi Emirate and a greater risk of inundation and coastal disasters.

Through modifications to our natural coastal systems due to the growing intensity of human activities and climate change, the emirate's exposure to storm-induced erosion and flooding could be affected. An overwhelming majority of the UAE's population lives near the coast and a dominant share of economic activity occurs in inundation-vulnerable, urban centres such as Abu Dhabi City [26]. Many coastal residents and economic activities can be found in areas that are backfilled or reclaimed from the sea for development projects. These areas are valuable commercial property and are particularly vulnerable to sea level rise impacts because of their low elevation above sea level. Consequently, the infrastructure supporting such properties and activities (such as roads, telecommunications, tourism facilities and wastewater networks) will face varying degrees of risk [10].

Of particular interest is the extent to which Abu Dhabi Emirate's natural coastal systems can provide important climate change adaptation benefits. Such systems provide a basis for building resilience to the coming adverse impacts in coastal areas associated with climate change. The underlying perspective is that healthy coastal-marine ecosystems are part of the emirate's natural capital that is essential for sustaining human life.

Impacts to Biodiversity

Despite extreme climatic conditions, Abu Dhabi Emirate's terrestrial and marine habitats provide many ecosystem goods and services, including the production of food, fisheries, tourism, recreation, protection from coastal erosion and sequestration of atmospheric carbon dioxide. However, the emirate's biodiversity is impacted by a variety of stressors, such as urbanisation, over-exploitation, habitat fragmentation and pollution, which reduce their resilience. Climate change acts in synergy with these factors, exerting additional pressures on biodiversity and reducing the ability to deliver critical goods and services.

Marine and Coastal Biodiversity

The major impacts of climate change on marine biodiversity are the effects of sea level rise and increased temperatures, salinity and acidification. An increase in the frequency and length of positive seawater temperature anomalies is likely the greatest threat to coral reefs. Mortality associated with coral bleaching events resulted in a 98 % loss of branching corals (Acropora) in 1996 on reefs in Abu Dhabi Emirate's waters, as well as the mortality of many of the remaining colonies during the 1998 bleaching event [27]. Coral communities in Abu Dhabi Emirate have still not recovered from the bleaching events of the 1990s [14].

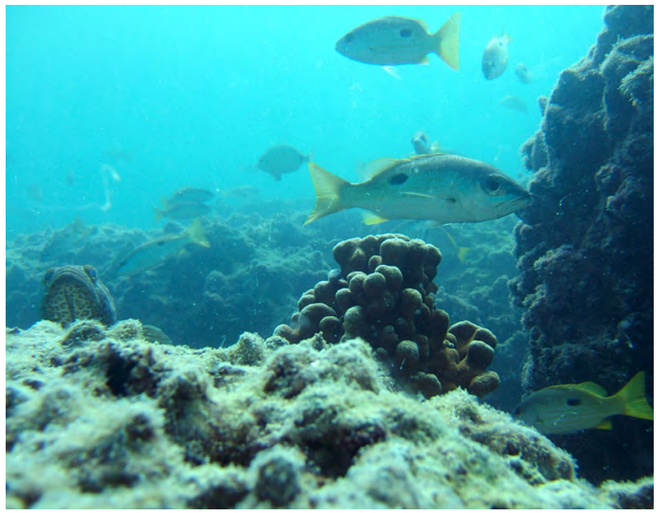
Bleaching events have recurred with increasing frequency in recent years, hampering the recovery of coral communities [28]. The reproductive output of several coral species has been shown to be impacted by bleaching events, suggesting that this may limit recovery through the next generation [29]. These changes are also impacting other reef-associated fauna such as fish, with reef-dependent species showing increasing vulnerability to extinction on southern Gulf reefs [30].

The threats of climate change to fisheries include changes in distribution, migration patterns and abundance due to increasing sea water temperatures. Changes in habitat quality and primary production may also affect productivity. There are also increasing risks of larvae failing to mature, particularly given that many larvae are considered to be close to their thermal tolerance limits [31, 32, 33].

Degradation of reefs caused by recent thermal stressors is considered a major threat to reef-associated fish in the UAE [30]. Predicted declines in fish yields will also have negative socio-economic implications for fishers.

Marine life in the Gulf is much less diverse than elsewhere in the Indo-Pacific due to the extreme environmental conditions and constraints on larval supply [34, 35]. For example, some species of reef fish are considered to live within 1°C of their thermal tolerance limits, at least for part of the year [36]. In addition to increased temperatures, increasing salinity levels are also expected to impact marine biodiversity, particularly in the coastal zone. Coral populations show systematic decreases in numbers of species with increasing salinity along the coast of Abu Dhabi Emirate [12, 13]. As such, it is expected that increasing salinity levels will also reduce species' diversity.

Coral reefs are very vulnerable to an increase in sea temperature, with the risk of bleaching



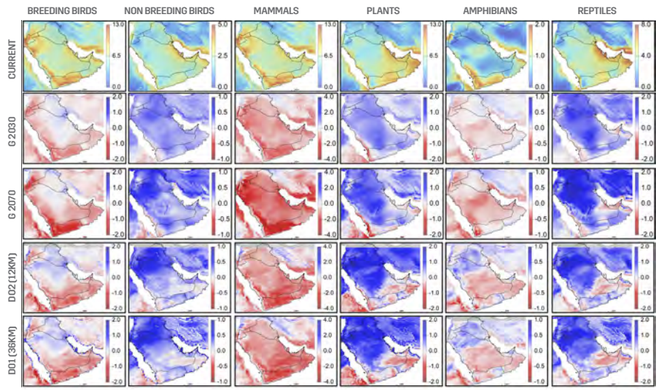
The direct effects of a rise in sea levels will be an increase in water depths, changes in tidal variation, altered water movement and greater seawater intrusion [37]. Tidal height and tidal range affects available light, current velocities, depth and salinity distribution, factors that regulate the distribution and abundance of shallow water marine ecosystems such as mangroves, coral reefs and seagrass beds. Therefore, a major impact of climate change will be a redistribution of existing habitats.

The impact of sea level rise on important marine wildlife populations will primarily be due to the loss of habitat. Nesting sites for marine turtles and seabirds, such as the globally threatened Socotra Cormorant (*Phalacrocorax nigrogularis*), may also be affected by rising sea levels. When coupled with storm surges, shoals containing seabird nesting colonies and areas of turtle nesting beaches may be periodically inundated or badly eroded. An increase in sand temperature will influence the sex ratio and viability of turtle hatchlings, with negative impacts for some critically endangered species such as the Hawksbill Turtle (*Eretmochelys imbricata*).

Terrestrial Biodiversity

Given that many plants in the region exhibit adaptation to extremes of heat and drought [38], much of the emirate's vegetation may be considered already highly resilient to climate change. However, species in drylands often exist near the limits of their physiological tolerances [39]. Climate change will likely act as an additional stressor that exacerbates ongoing degradation from the severe impacts of over-grazing and change in land use in many areas [40]. Perhaps more significantly, climatic and other conditions required for regeneration can differ from those in which established plants can persist [41], and

FIGURE 8.5 Mean Current Habitat Suitability and Projected Change in Habitat Suitability Across All Priority Species by Taxonomic Group for Global (2030 and 2070) and Regional (2070 only at 12 and 36 km resolution)



SOURCE: AGEDI [42]

as such future climate change may hinder colonisation of disturbed areas or newly suitable habitats and the replacement of individuals lost to mortality.

In addition, climate-driven changes in vegetation will also likely impact the emirate's bird species. In the recently completed AGEDI Regional Terrestrial Biodiversity Vulnerability to Climate Change study, breeding birds, mammals, and amphibians were projected to have the most extensive reductions in suitable habitat, which covered nearly the entire study region for these taxa. In contrast, nonbreeding birds, plants, and reptiles were projected to gain suitable habitats across much of the study region.

As is the case with other dryland taxa, many desert mammals exist near the upper lethal limits of temperature and have limited access to water. For these reasons, climate change is expected to have severe consequences across a wide range of desert animals [43].

Water Nexus

Under current conditions, the Arabian Gulf is already one of the most stressed marine environments on earth. Furthermore, an increasing share of the water supply comes from desalinated water, which requires energy to produce. This suggests that reliance on desalination is as much of an energy challenge as it is a water challenge [44].

The intensification of desalination activities within an already stressed Arabian Gulf may pose a range of environmental implications under climate change. Desalination processes separate seawater into freshwater, which is then distributed to meet the freshwater demands of households, businesses, amenities and industry. Hot brine concentrate from the desalination process is disposed into the Arabian Gulf, leading to localised changes in temperature and salinity levels [44].

Completed in 2016, the AGEDI National Water Nexus study investigated the following dimensions:

i) the impact of increasing ambient temperatures and changing precipitation on both water and energy demands in the context of socioeconomic growth; and
ii) the costs and benefits associated with a transition to more efficient and renewable-intensive water/energy production and consumption patterns [45].

Health and Wellbeing

Climate change will have significant impacts on public health, affecting key social and environmental determinants such as clean air, safe drinking water, sufficient food and secure shelter [5, 46]. The World Health Organisation (WHO) considers a changing climate as the greatest threat to global health in the 21st century. It noted that climate change already claims tens of thousands of lives each year due to heat waves and other extreme weather events, outbreaks of infectious diseases, the effects of malnutrition and environmental pollution.

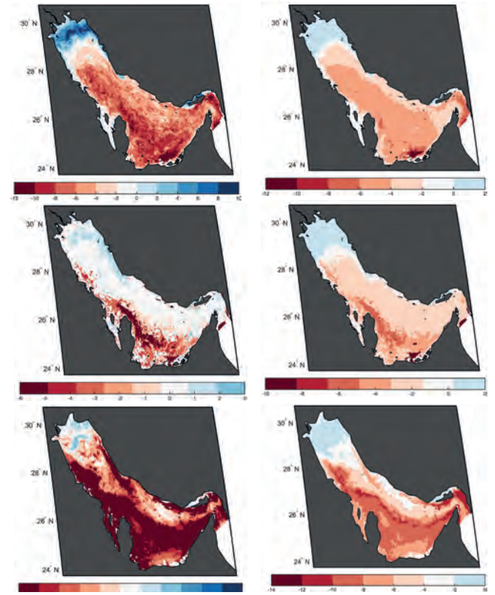
The major impacts of climate change on the UAE's public health are expected to be increased heat stress, potentially increased water- and vector-borne diseases, reduced water availability and impacts on food security [47]. The total burden of disease from climate change is difficult to ascertain, as there are many mechanisms through which climate change can affect public health [5]. The WHO global burden of disease model estimates for the UAE and the Middle Eastern region show low health effects from climate change relative to other countries, with an estimated 14 Disability-Adjusted Life Years (DALYs) *per* 100,000 people [48]. For the UAE, models have shown that climate change currently has minimal effects on human health relative to other modelled priority areas: approximately only 410 (0.2 %) additional healthcare facility visits and 2 to 3 (0.1 %) additional premature deaths from cardiovascular disease in 2008 were due to added risks of climate change. Assuming a 'do-nothing' scenario, the health burden due to climate change in Abu Dhabi Emirate is expected to increase to an approximate additional 27 premature deaths and 3,545 healthcare facility (HCF) visits *per* year. This figure would be approximately 16 premature deaths and 2,130 HCF visits if CO_2 levels could be stabilised at 550 ppm or 750 ppm levels. No estimates are available for non-cardiovascular health effects, such as malaria, malnutrition, flooding deaths and diarrhoea; however, these are expected to be low [49, 50].

Food Security

Considering the UAE's heavy dependence on food imports and limited supply of fertile land and fresh water, food security is a key issue for Abu Dhabi Emirate. The Economist's annual Global Food Security Index for 2016 ranks the UAE 30th out of 113 countries, according to criteria based on food affordability, availability and quality.

However, the UAE may be vulnerable to food supply constraints and any associated price shocks associated with climate change impacts in food-exporting countries. The combination of climate change-induced declining agricultural productivity in food-exporting countries, tightening of world food markets and price speculation pressures could lead to several adverse circumstances in the UAE. These may include recurrent retail food price spikes and a need for substantial food subsidies. Households that have annual incomes at the lower end of the national range could find themselves subject to spending a growing share of the household budget on food [51].

FIGURE 8.6 Projected Changes in Species Richness (left) and Habitat Suitability (right) for the 47 Priority Fish Species by 2090 Relative to 2010 Under RCP 8.5



SOURCE: AGEDI [51]

Additionally, climate change is predicted to have significant adverse impacts on commercial fisheries in the Gulf. This is illustrated in Figure 8.6, which shows the impacts of climate change on species richness and habitat suitability 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 (see Figure 8.6 and Box 8.1).

Climate change could also impact domestic agriculture in the UAE, due to a number of factors leading to an overall decline in agricultural output. These include increased mean temperatures, reduced availability of freshwater resources, increased short-term weather hazards, soil erosion and loss of arable land, and increased disturbance from fires, plant diseases and pest outbreaks [51, 5]. In the absence of adaptation, the production of vegetables, fruit crops and field crops is threatened by climate change as it increases vulnerability to existing stresses [5].

8.4 Responses

The UAE Government is fully committed to the United Nations Framework Convention on Climate Change negotiating process. The UAE's INDC in terms of mitigation and adaptation actions is described in Figure 8.7.

These are mainly based on a strategy of economic diversification that will yield co-benefits in terms of both mitigation and adaptation as summarised below [52]. EAD supported the preparation of the INDCs through preparing the content for Abu Dhabi Emirate in cooperation with emirate-level stakeholders.

At a federal level, MOCCAE is coordinating all climate change-related activities.

Mitigation

Energy Sector

Clean Energy Targets

Abu Dhabi Emirate is following a whole-of-government approach to meet its commitment in contributing to national targets. These aim to increase the contribution of clean energy to the total energy mix from 0.2 % in 2014, to 27 % by 2021. This will be achieved through the use of renewable and nuclear energy.

Energy-intensive industries and the oil and gas sector will continue to use innovative technologies to improve efficiency and reduce emissions.

Abu Dhabi National Oil Company (ADNOC) was the first in the region to reduce gas flaring, in order to lower GHG emissions. In energy intensive industries, overall performance indicators will be improved through carbon abatement measures and increased resource efficiency.

In 2016, Abu Dhabi Emirate launched the region's first commercial-scale network for carbon capture, usage and storage. The project notably captures and compresses emissions at the Emirates Steel facility in Musaffah. This is compressed and transported to oil fields, where it is used to enhance oil recovery and ultimately stored underground, providing one of the first viable mechanisms to de-carbonise essential energy-intensive industries.

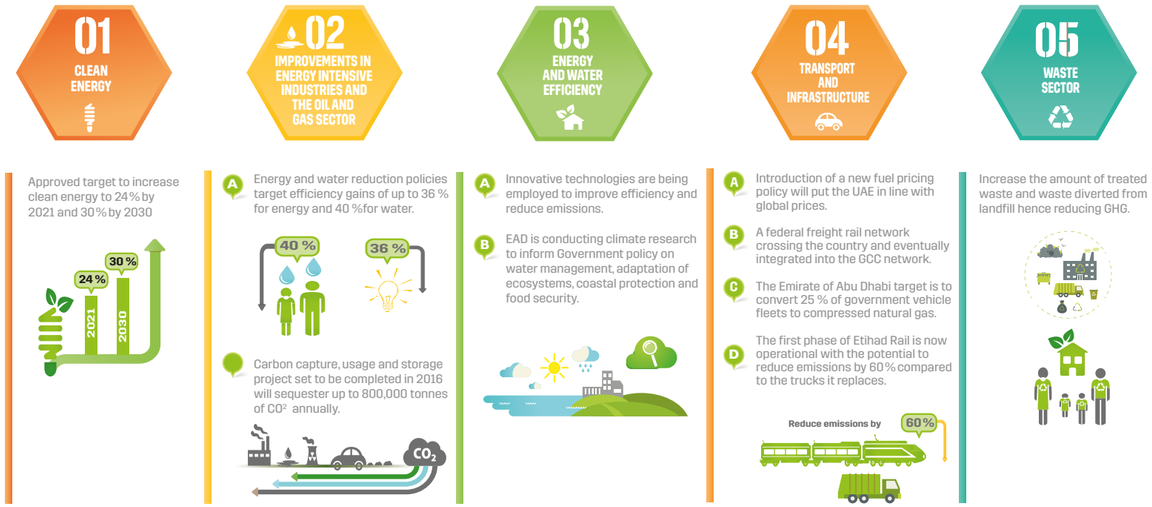
ADNOC is among a number of companies in Abu Dhabi Emirate using innovative technologies to reduce GHG emissions

Energy and Water Efficiency

In addition to supply side targets, Abu Dhabi Emirate is undertaking comprehensive policies to reduce energy and water demand and promote the prudent use of resources. This includes the following actions:

- Tariff reform: the emirate recognises the value of energy and water tariff reform in reducing inefficiencies and promoting low-carbon development, as well as addressing energy security concerns. To this end, utility authorities have introduced a number of initiatives and policies, revising tariffs over the years for commercial and industrial customers, so as to reflect the cost of generation by 2021.
- Building and efficiency standards: Abu Dhabi Emirate is comprehensively targeting emissions from its building sector, which account for a significant percentage of the country's electricity and water consumption. This is being achieved through green building regulations, efficiency standards, retrofit programmes and support structures for energy service companies.
- Demand side management: Abu Dhabi Emirate also launched a number of initiatives based on consumer awareness and demand management, including new formats for water and electricity bills that give residents detailed consumption and subsidies information.
- District cooling: given the harsh climate in Abu Dhabi Emirate, air-conditioning accounts for a significant share of energy consumption. Comprehensive infrastructure investments are being undertaken to move away from decentralised cooling and towards district cooling and improved efficiency.
- Appliance efficiency standards: Abu Dhabi Emirate collaborates with other emirates in developing the region's first efficiency standards for air-conditioning units, eliminating the lowest performing 20 % of units on the market. It is also introducing efficiency standards for refrigeration and other appliances.

FIGURE 8.7 UAE Strategies to Reduce GHGs



SOURCE: EAD

Transport and Infrastructure

The Emirate of Abu Dhabi has adopted a comprehensive urban structure framework plan to optimise the city's development until 2030.

The emirate is undertaking the following investments and initiatives, which will have significant mitigation co-benefits in addressing the transport sector's GHG emissions, including:

- The introduction of a new fuel pricing policy, which will put the UAE in line with global prices. This aims to support the national economy, lower fuel consumption and protect the environment.
- A federal freight rail network crossing the country that will be eventually integrated into the GCC network.
- Targets to shift 25 % of government vehicle fleets to run on compressed natural gas.
- Strategies for Low Emission Vehicles (LEVs) and Low Emission Zones (LEZs), both aiming to reduce air pollutants and GHG emissions from the transportation sector.

Waste Sector

Abu Dhabi Emirate will increase the amount of treated waste and waste diverted from landfill through a number of key initiatives, including:

- Developing laws to regulate and oversee waste management.
- Defining a federal roadmap for integrated waste management.
- Creating a database to gather and collect information regarding waste.

Adaptation

Abu Dhabi Emirate is expected to be affected severely by a changing climate. Because of this, adaptation is equally as important as mitigation, and in some cases adaptation actions do have mitigation co-benefits.

Water Management

The booming economy and industrial development in the UAE have increased water demand over the last few decades. This demand has largely been met by desalination, with seawater desalination plants producing 98 % of the water consumed in the municipal sector (including potable, industrial and commercial use). Climate change, rapid population growth, industrial development, urbanisation and demand for agricultural irrigation will all have an impact on future water resources in the UAE and Arab region as a whole.

In the UAE, there is concern about further growth in the demand for agricultural water, particularly during the productive winter months, when, in the event of climate change, temperatures will be higher and evapotranspiration greater. This could further stress scarce groundwater resources.

The economic and environmental cost of desalination will also increase as the climate changes. Projections suggest that the Arabian Gulf – the primary feedstock of desalination plants in the UAE – is likely to become warmer and more saline. Additionally, the risk of disruption to desalination supply due to extreme events (such as storms or algal blooms) could also increase with climate change. Abu Dhabi Emirate is undertaking a Water Conservation Plan and more efficient forms of desalination.

Wetlands, Coastal and Marine Environment Conservation (Blue Carbon)

The coastal and marine environments of Abu Dhabi Emirate are diverse and include mangrove forests, salt marshes, sabkha, intertidal mudflats with cyanobacterial mats, and extensive sub-tidal seagrass meadows.

The emirate is undertaking significant restoration and plantation efforts, as well as conservation planting of both mangroves and seagrass, both of which support ecosystem-based adaptation resulting in mitigation of CO_2 with co-benefits of adaptation.

In 2013, the UAE and AGEDI initiated the Blue Carbon Demonstration Project, which provided decision-makers with a stronger understanding of the carbon sequestration potential in the Emirate of Abu Dhabi. In 2014, the project's scope was expanded to cover the entire country, and it is now known as the UAE's National Blue Carbon Project.

Overall, Blue Carbon ecosystems in Abu Dhabi Emirate are calculated to store more than an estimated 41 million tonnes of CO_2 equivalent within the soil and biomass, more than the emirate's annual emissions from the oil and gas (26.4 million tonnes) or water and electricity (30.9 million tonnes) sectors.

A comprehensive coastal management approach is urgently required, which will protect the wetlands and coastal habitats and address issues linked with other drivers, such as climate change in relation to coastal vulnerability and the loss of coastal and marine resources (if critical towards adaptation planning). The Marine Spatial Planning initiative, spearheaded by the Department of Urban Planning and Municipalities (DUPM), could be complemented with a broader coastal zone management programme.

The emirate's farmers are adopting new agricultural techniques to reduce water usage and improve productivity

Terrestrial Species and Habitats

Adaptation to climate change for terrestrial species and habitats is taking place through local and national biodiversity strategies. Resilience is being enhanced through the creation of a representative network of Protected Areas.

Food Security

In 2010, Abu Dhabi Executive Council established the Food Security Centre – Abu Dhabi (FSCAD), tasked with ensuring food security for the emirate. The centre's mandate includes: developing food security strategies, policies and regulations; establishing and managing emergency food reserves; preparing emergency plans in cooperation with the National Agency of Emergency and Crises Management; coordinating investments in the food sector in order to ensure security and support an increase in local production (agricultural, animal resources and fish resources); and achieving self-sufficiency in some food products.

As part of these efforts, Abu Dhabi Food Control Authority (ADFCA) and Abu Dhabi Farmers' Services Centre (ADFSC) have supported farmers in improving productivity levels and reducing the use of water and other inputs for agriculture. This has included better irrigation techniques, the adoption of protected agriculture (greenhouses and hydroponics) and crop substitution. More recently, EAD collaborated with a number of government entities to initiate the development of an aquaculture policy to promote fish farming in the emirate while ensuring the responsible utilisation of natural resources.

Innovation and Research and Development

The Abu Dhabi Government has invested heavily in world-class graduate education for sustainable energy development. It established the Masdar Institute for Science and Technology in partnership with the Massachusetts Institute of Technology. The emirate has also established the Local, National, and Regional Climate Change Assessment Programme, addressing the data challenges across the wider region related to climate change adaptation and vulnerability issues. The Zayed Future Energy Prize further supports innovation, and is one of the most prestigious accolades in the field of clean energy development.

Education, Training and Public Awareness

Abu Dhabi Emirate has begun reforming curricula in schools to improve science and training, including the field of climate change. Outside of academia, UAE Government entities have launched public awareness campaigns, including Waterwise, Powerwise, Heroes of the UAE, Watersavers, and the Sustainable Schools and Sustainable Campus Initiatives, as well as the Ecological Footprint Initiative.

8.5 Outlook

Looking Ahead

As seen in the above analysis of the driving forces and pressures of climate change, energy-related activities (such as fuel combustion) are the main sources of GHG emissions in Abu Dhabi Emirate. According to Abu Dhabi Water and Electricity Company (ADWEC) [53], the emirate's electricity demand is growing at double or triple the pace of economic activity and is expected to continue to grow. This high demand is partly related to the climate: more than 50 % of peak demand is used to meet the cooling load in summer. ADWEC estimates that increases in the demand for electricity in the near future will be dominated by electricity exports to the Northern Emirates and demand from ADNOC. In later years the demand will come mainly from industry and residential and commercial mega projects that are likely to become steadily more important as the Abu Dhabi Plan is delivered.

According to ADWEC's Winter 2012/2013 Water Demand Forecast [54], the emirate's desalination capacity is expected to double by 2030 to match demand, and its electricity generation capacity is expected to triple by 2030 to match demand. However, the emirate's water and electricity policy is gradually moving towards the more active promotion of conservation and efficient use and supply of water and electricity. Part of the future power capacity of Abu Dhabi Emirate will be provided by low-carbon energy (renewable and nuclear). This will contribute to mitigation of future GHG emissions. In 2017, the emirate launched a project to build the biggest solar power station in the world, with a capacity of 1,177 MWh. When combined with existing solar power sources, the share of renewable energy in Abu Dhabi Emirate will be 7 % upon completion of the project.

If development plans continue according to the business-as-usual (BAU) scenario in 2010, future GHG emissions in Abu Dhabi Emirate are expected to increase by a factor of 3.0, from 99.1 million tonne CO_2-eq in 2010 to 297.5 million tonne CO_2-eq in the year 2030 [18], (considering policies as in the base year 2010 and taking into account the expected changes in population, GDP and urbanisation). In this scenario, by 2030 sectoral GHG emissions might be increased by 330 %, 220 %, 150 % and 300 % for energy, industrial processes, agriculture and waste, respectively. AGEDI is collaborating with Climate Change Research Group (CCRG), National Center for Atmospheric Research (NCAR) and the University of Sao Paulo (USP). The collaboration aims to improve future climatic projections in the Gulf region by creating a high-resolution regional model that is based on the Intergovernmental Panel on Climate Change (IPCC)

BOX 8.1 What is an RCP?

Representative Concentration Pathways (RCPs) are four GHG concentration (as opposed to emission) trajectories the IPCC used in its 5th Assessment Report. RCPs supersede the previous GHG storylines (e.g. A1, B1). RCP8.5 can be considered analogous to a business-as-usual scenario. The other RCPs assume stabilisation of GHG emission concentration in the atmosphere prior to 2100.

Global Climatic Models (GCMs). These models are typically poor in regions such as the Gulf due to the complex terrain, surface winds and sea surface temperatures [45, 25]. Higher-resolution regional models better account for such complexities.

Key findings of the modelling found the potential for the following:

- Rainfall in the UAE will likely increase, especially in the summer months (e.g. 50-100 % in the Northern Emirates and Dubai and 25 % in surrounding regions).
- Temperature will increase between 2 and 3°C by the end of the century.
- Wind patterns will change in terms of their magnitude and direction, depending on the season and time of the day (e.g. there will be stronger winds from the interior during winter, and stronger winds in evening hours during summer).

New urban development leads to increased demand for energy

- Extreme weather events, such as cyclones, are predicted to take place in the late 21st century.
- Sea surface temperatures are projected to increase throughout the Arabian Gulf, from 1°C by mid-century, to up to 2.8°C by late century.
- Sea surface salinity is projected to both decrease and increase, depending on location. By mid-century, an uneven distribution of salinity is observed throughout the Arabian Gulf.
- Sea level is projected to rise throughout the Gulf by mid-century. The estimation of sea level rise was very conservative (3 to 10 cm). The model only considered the effects from storm surges and ocean circulation, which typically account for up to 15 % of regional sea level rise. Due to limitations in the current state-of-the-art ocean modelling, ice cap melting and thermal processes (which are the major factors contributing to sea level rise) could not be directly modelled. Therefore, further study is needed to incorporate the effects of deglaciation and global ocean thermal expansion on sea level rise.
- Dynamic sea level (DSL) rise is highest in the northern area of the Gulf, and by late century, the areas showing the lowest increases are in the central Gulf area.
- Annual circulation dynamics are expected to change in two zones: a deep zone located in the central area, and a shallow zone located along the UAE coast.
- Global climate change effects from wind patterns will have impacts on Gulf coastal currents for two locations near Qatar and the UAE. Wind effects will be more evident in shallow areas, where coastal currents are well defined and highly correlated with wind, especially northward winds.

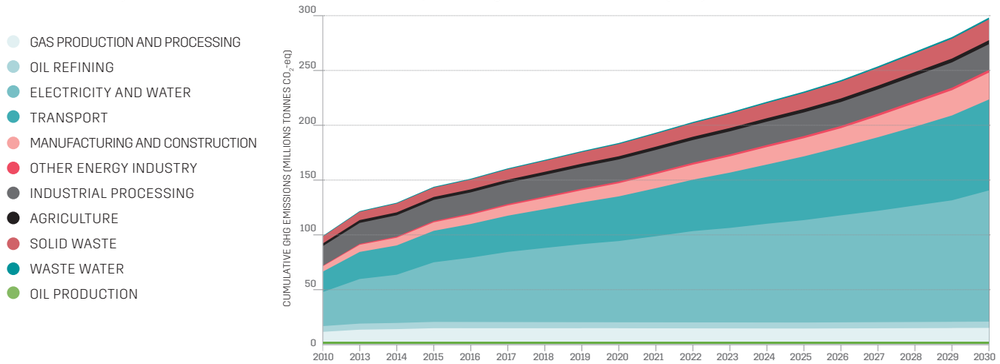
Changing Course

Initial analysis of the future opportunities for GHG emission mitigation [18] shows that the emirate has the potential to reduce around 42 % of its BAU emissions by the year 2030. This will be achieved by considering additional emission control measures and policies, in a so-called extended emission control scenario BAU-EXEC (Figure 8.9). The key mitigation strategies that were considered in the analysis are:

- Nuclear energy programme
- Renewable energy programme
- Electricity and water demand side management (DSM) programme
- Surface transport master plan
- Estidama programme
- Oil and gas Environment. Health and Safety (EHS) programme
- Waste sustainable management programme
- Carbon capture and storage project
- Energy efficiency programme for the production of aluminium, oil and gas, electricity and water

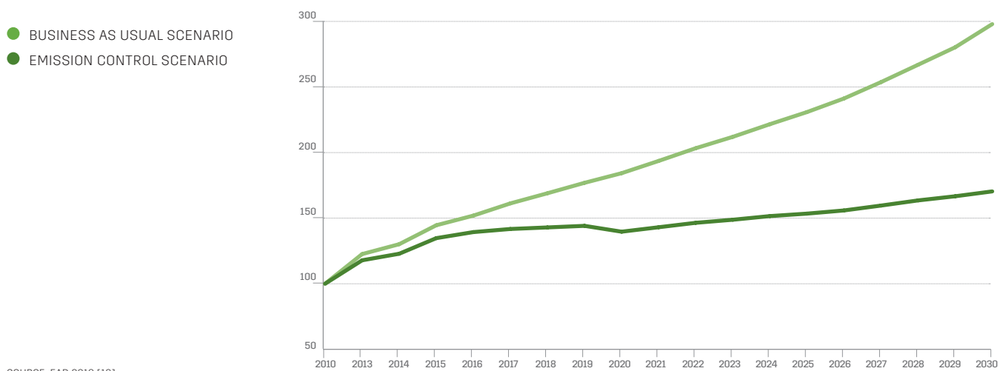
The largest potential for emission reductions in the year 2030 is expected to come from combined electricity and water production (22 % of BAU emissions), followed by transport (12 %), waste (6 %), and other sectors (2 %). By the year 2020, nuclear and renewables will cover around 30 % of energy demand and avoid 22 million tonnes of CO_2-eq per year. However, these initial projections and analysis will need to be reviewed and updated where necessary in close coordination with MOCCAE and other relevant stakeholders.

FIGURE 8.8 **Projected Sectoral GHG Emissions until 2030, According to Business-as-Usual (BAU) as in 2010**



SOURCE: EAD 2016 [18]

FIGURE 8.9 **Projected GHG Emissions until 2030 for Abu Dhabi Emirate, According to Emission Control Scenario (BAU-EXEC)**



SOURCE: EAD 2016 [18]

FISHERIES

LEAD AUTHOR – AYESHA YOUSEF AL BLOOSHI
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KEY MESSAGES

DRIVERS

The emirate's rapidly growing population and expanding tourism sector are increasing the demand for seafood.

PRESSURES

Over-capacity in the fishing fleet, coastal development, cumulative desalination activities and pollution, as well as climate change, cause pressure on the emirate's fisheries.

STATE

Abu Dhabi Emirate's principal fisheries resources have experienced severe over-exploitation as a result of these pressures. There has been an estimated 90 % decline in abundance of commercially exploited demersal species over the past 30 years.

IMPACTS

This decline in the state of Abu Dhabi Emirate's fisheries causes social, economic and environmental impacts. Fisheries' contribution to future food security is jeopardised, as is the opportunity for employment in the sector. There is also a loss of recreational value and tourism opportunities. A reduction in ecosystem function may have far-reaching effects on Abu Dhabi Emirate's maritime domain.

RESPONSES

A comprehensive UAE-wide fisheries change management programme is being undertaken. Known as the UAE Sustainable Fisheries Programme, this is being implemented to ensure the continuity of Emirati fishing traditions, targeting a sustainably-utilised fishery by 2030.

9 Introduction

KEY INDICATOR OF CURRENT STATE: **7.6 %** OF FISH HARVESTED SUSTAINABLY IN 2015

As a coastal settlement, the history of Abu Dhabi Emirate is closely linked with the fishing industry

Fisheries – An Integral Part of the UAE's Heritage

The waters of the Arabian Gulf, its islands, coastlines and fisheries, are of fundamental importance to the people of Abu Dhabi Emirate, the UAE and the region. Historically, the emirate's fishery resources sustained the population. Fishing and harvesting marine resources were integral to their survival, with the sea linking Abu Dhabi Emirate to the Arabian Gulf region and the rest of the world. Whether on the coast or inland, all life in the emirate and wider UAE was fundamentally connected to fishery resources and the maritime domain.

Abu Dhabi Emirate – An Important UAE and Global Fisheries Stakeholder

Abu Dhabi Emirate is an important fisheries stakeholder in the UAE, with 72 % of the UAE's Arabian Gulf marine area falling within the emirate's waters. Changes in the abundance of demersal fish species in Abu Dhabi Emirate's waters are a very good indicator of the overall state of the UAE's Arabian Gulf fishery. For migratory species, such as the pelagic Kingfish (*Scomberomorus commerson*), the UAE is an important regional fisheries stakeholder.

On a global level, the resilience of Abu Dhabi Emirate's fisheries in extreme fluctuations in seawater temperature, in addition to anthropogenic pressures, provides a good ongoing case study for fishery resilience and management adaption in the context of climate change (see Chaper 8 – Climate Change).

9.1 State

29 % of seafood in the UAE is contributed by the catch of local fisheries

Socio-Economic Overview

Fishing Distribution – East and West

In geographic terms, fishing in Abu Dhabi Emirate occurs in two distinct regions within the emirate's 46,000 km^2 maritime area: the Western Zone and the Eastern Zone (see Map 9.1). The Western Zone is defined as the coastal zone from Al Mirfa to the border with Saudi Arabia and Qatar. It includes Al Mirfa, Delma and Sila Commercial Landing Areas. The Eastern Zone is defined from Al Mirfa to the border with Dubai. It includes Al Bateen, Al Saadiyat, Al Sadar and Free Port Commercial Landing Areas [1]. In addition, there are 40 recreational fishing landing sites across the emirate.

Fishing Methods – an Artisanal Fishery

The UAE fisheries sector, comprising both commercial and recreational subsectors, has maintained its traditional links and is artisanal in nature.

A mix of lansh (motored dhows) and tarad (open fibreglass motor-powered vessels) operating across the emirates use traditional methods including gargoor (fish traps) and ghazel (encircling gill nets). The traditional al hadhra (fixed fish trap using stakes) is used nearshore in Abu Dhabi Emirate, with land-based dhagwa (beach seining) confined to the northern and eastern emirates (Ras Al Khaimah and Fujairah). Hadaq is the traditional hook-and-line method practised in the recreational fishing subsector, in addition to spearfishing, which is gaining popularity with a younger generation of recreational fishers.

UAE Licensed Fishers

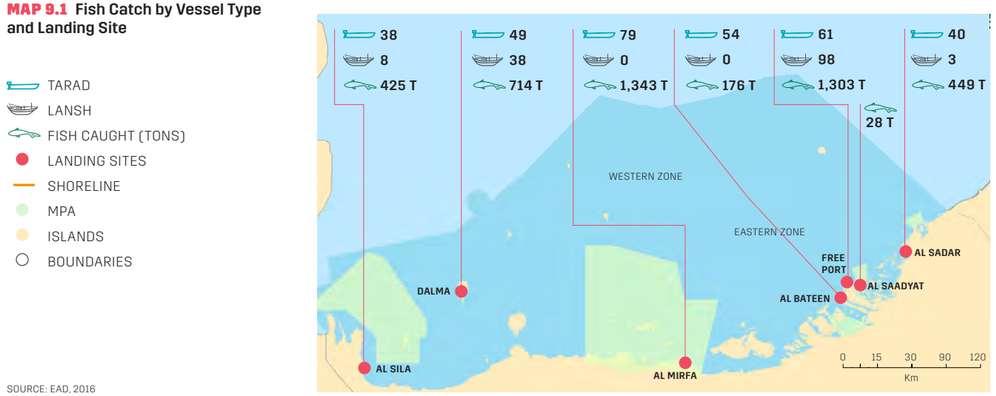
According to the Ministry of Climage Change and Environment (MOCCAE), there are approximately 5,115 national and 13,288 expatriate commercial fishermen in the UAE, operating in 5,985 vessels [2]. Some 16,000 recreational vessels are registered by the Federal Authority for Land and Sea Transport (although it is unknown whether this number are used for fishing activities), indicating that at UAE level, this sub-sector contributes to a large proportion of fishing pressure [3].

Commercial Fishing

In Abu Dhabi Emirate there are 147 licensed and active lansh (31% of the Abu Dhabi fleet) and 321 licensed and active tarad (69%).

There are 2,818 active commercial fishers in the emirate, with vessels crewed by 468 Emirati fishers and 2,350 expatriates. Landed catch from the commercial sector is estimated at 70 % of the overall landed catch in the emirate, equal to 4,438 tonnes per year [6].

MAP 9.1 Fish Catch by Vessel Type and Landing Site



SOURCE: EAD, 2016

Recreational Fishing

There are 3,164 licensed recreational fishers in Abu Dhabi Emirate, including 1,225 Emirati fishers and 1,939 expatriates. This sub-sector accounts for 55 % of all fishing licenses in the emirate, with the amount of landed catch from this sector considered to be 30 % of the emirate's total landed catch, equal to 1,331 tonnes annually [4].

Economics and Cultural Importance

Economically, the UAE fishing sector comprises only 0.12 % (AED 1.8 billion) of the country's GDP. Similarly, in Abu Dhabi Emirate the total ex-vessel value of the landed catch for the commercial fishery is estimated to be less than 0.0077 % of the emirate's GDP, in the region of AED 128.3 million [5].

The gross value added (GVA) from others in the supply chain is not known.

The economic contribution of the fisheries sector is relatively small in terms of the overall output of Abu Dhabi Emirate and that of the UAE. However, this is outweighed by the cultural importance and significance of the fishery to the UAE population.

UAE Seafood Imports

Currently the UAE imports 70 % of seafood products, with the remaining 29 % from local fisheries catch and 1 % from aquaculture [5].

Fisheries Science

Fisheries Scientific Research Programme

Since its inception in 1996, EAD has been at the forefront of scientific research and management of the emirate's and wider UAE's fisheries in pursuit of sustainability. In 2001, EAD began an annual scientific stock assessment research programme in recognition of the pressures on fisheries. After 15 years, this has resulted in the assessment of 28 key commercial species, providing the UAE's Arabian Gulf fishery with annual scientific indicators for the state of the fish stock.

Additional detailed information can be found in the Annual Fisheries Statistical Report for Abu Dhabi Emirate [6] (available for download from the EAD website).

Sustainability Indicators

EAD has been monitoring the state of fish stocks against two key sustainability indicators. The first is the Spawning Biomass *per* Recruit (SBR) (a proxy for adult stock size) of key demersal species when compared to a virgin biomass. This includes: Hamour (Orange-spotted Grouper – *Epinephelus coiodes*),

Shaari (Spangled Emperor – *Lethrinus nebulosus*) and Farsh (Painted Sweetlips – *Diagramma pictum*). The second is the Sustainable Catch Index, which describes the proportion of catches of species that are sustainably exploited.

The SBR indicator is derived from population models with input parameters relating to population dynamics (e.g. growth rate and age at maturity) and fishery characteristics (e.g. age at first capture and fishing mortality rate). Analysis of the relationships between stock sizes and recruitment have produced biological reference points against which the SBR is compared in order to infer the status of the population (and whether it is over-exploited).

A Severely Over-exploited Fishery

By 2015, a more than 90 % decline in the adult (reproductive) stock size in Abu Dhabi Emirate had been estimated for the three key demersal indicator species (Hamour, Shaari and Farsh). For the Hamour, the level was the lowest, approximately 4.7 % of the average adult stock size. The international sustainable fisheries management threshold is 30 %. Below this figure, stocks are considered to be over-exploited [5].

Fourteen species caught in Abu Dhabi Emirate's waters are over-exploited

The UAE and Abu Dhabi Emirate's fisheries scenario is consistent with the decline in global fisheries resources: 90 % of global fish stocks are in decline, of which 28.8 % are reported as being over-exploited and 61.3 % as fully exploited.

The Sustainable Catch Index describes the proportion of the total landed catch that is sustainably exploited species (those caught above the 30 % threshold). In 2015, only 7.6 % of fish species caught in Abu Dhabi Emirate's waters had abundance higher than the 30 % sustainable threshold.

Over-exploitation

Fourteen species in Abu Dhabi Emirate's waters are currently over-exploited: 11 are caught with gargoor (fish traps targeting demersal species) and three are caught with ghazel (an encircling net targeting pelagic species) [6].

In addition to regionally iconic species such as the Hamour, Shaari, Farsh and Kingfish, other over-exploited species include: Dhil'e (Talang Queenfish – *S. commersonnianus*), Zuraidi (Golden Trevally - *Gnathanodon speciosus*), Jesh Um Al Hala (Orange-spotted Trevally - *Carangoides bajad*), Shaari Eshkheli (Pink Ear Emperor - *Lethrinus lentjan*), Yemah (Snub-nosed Emperor - *Lethrinus borbonicus*), Qabit (Gold-lined Seabream - *Rhabdosargus sarba*), Safi Arabi (White-spotted Spinefoot - *Siganus canaliculatus*), Kofar (King Soldier Bream - *Argyrops spinifer*), Esnenuh (Yellow-fin Hind – *C. hemistiktos*) and Marjaan (Mangrove Red Snapper - *L. argentimaculatus*).

Additional Studies

Additional independent scientific studies corroborate that Abu Dhabi Emirate's fisheries are severely over-exploited:

- In 2002-2003, EAD commissioned a vessel-based Fisheries Resources Assessment Survey of the UAE's Arabian Gulf waters. At that time, it showed that demersal fisheries resources were approximately 19 % of their virgin biomass. This indicates that the fishery was already over-exploited 13 years ago [7].
- A 2011 EAD study compared coral reef fish abundance within and outside Abu Dhabi Emirate's protected areas. It concluded that coral reefs outside of protected areas had less than 20 % of the abundance of those within these areas [8].
- Discrete MOCCAE assessments of size and length composition data derived from the northern and eastern emirates (with the exception of Dubai and Fujairah) have indicated that the status of key demersal species in other locations within the UAE is no different than that determined in the Emirate of Abu Dhabi [9].
- Two additional surveys, completed for the GCC between 1976-79 (UN FAO) and in 2010-11 (KISR), investigated the entire Gulf region and included relatively few sampling stations in the UAE – results from the sampled stations also indicated a low abundance of demersal resources [10, 11].

EAD's survey shows that the emirate's fishing workforce is ageing, with an average age of circa 50

Socio-economic Studies

Additional socio-economic studies support the evidence that the emirate's fisheries are severely over-exploited.

In a targeted socio-economic survey of fishers in Abu Dhabi Emirate and the wider UAE (2014-2015), circa 80 % of the most experienced fishers across the emirates agreed that the fishery was severely over-exploited and had declined significantly. Anecdotes included using 'few gargoor' in the past which caught 'many fish', and the need to use 'too many' gargoor now to catch 'few fish'.

The survey indicated that there was motivation among fishers for change in the sector. It also confirmed that fishers in the commercial sector are ageing (with an average age of circa 50). There is a perceived lack of interest among the younger generation for a career in fishing [12, 13].

Through the completion of the socio-economic survey in 2015, and corroboration from science and socio-economics, there was an irrefutable case for change in the fisheries sector in Abu Dhabi Emirate.

Fisheries Resources Assessment Survey 2016

EAD commissioned a UAE Arabian Gulf Fisheries Resources Assessment Survey in 2016. This was in recognition of the severely over-exploited state of the fisheries of Abu Dhabi Emirate and the wider UAE, plus the identified need to have an accurate baseline stock abundance level in order to estimate the current stock status and compare future changes in stock levels.

9.2 Drivers & Pressures

Increasing Demands on the Maritime Domain and Fisheries Resources

With the rapid increase in the population of Abu Dhabi Emirate over the past two decades (see Chapter 2 – Driving Forces of Environmental Change), and the resulting increased demand for seafood and other uses of the maritime domain, the UAE's fisheries have come under increasing pressure.

Consistent with global trends, pressures on Abu Dhabi Emirate's fisheries have included:

- Increased demand for fish due to a rapidly growing population and tourism industry.
- Loss and degradation of key habitats and marine water quality, due to coastal development, cumulative desalination activities, pollution and climate change [14] (see Chapter 6 – Marine Water Quality and Chapter 8 – Climate Change for details).
- Three separate climate change models have predicted that by 2090, there will likely be an additional decline in fish catch of up to 26 % due to climate change [15].
- Ocean acidification due to climate change, which affects the reproductive processes and survival of juvenile fish.
- Loss of mangroves and seagrass to coastal development, severely impacting fisheries resources due to a loss of nursery function.
- Increases in temperature, which may also affect fish directly in terms of their physiology.
- Illegal, unreported and unregulated fishing such as: the use of illegal fishing gear, catching of prohibited species or violation of size limits, and unreported and significant catch by the recreational fishing sector.

Sustainable catch targets have been set in the UAE Sustainable Fisheries Programme

Fishing Pressure

EAD studies indicate that one of the key pressures on Abu Dhabi Emirate's fisheries is the overcapacity of the commercial and recreational fishing sectors. In the wider UAE, the number of fishing vessels has increased from 1,065 in 1976 to 5,985 in 2015.

The most landed demersal species, Hamour, Shaari and Farsh, are being over-exploited by an estimated five times the sustainable limit, while the pelagic Kingfish is being over-exploited by up to three times its sustainable limit [5].

Additional pressure on fisheries comes from the ongoing loss of fish-associated coastal habitats, such as coral reefs, mangroves and sabkhas that are important for supporting fish (whether as energy and food or as habitat, for either juveniles or adults or both). These habitats are being lost and degraded by coastal development as well as climate-related pressures [16, 17]. Although data is scant, information from the UAE (and surrounding nations) suggests that impacts from ecosystem loss on fish populations are already occurring.

9.3 Impacts

The fishing industry is at the heart of Emirati culture, and its decline impacts society, the economy and the environment

Impacts

The impacts of a severely over-exploited fishery in Abu Dhabi Emirate are social, environmental and economic. Fishing and resourcefulness in the maritime domain is at the heart of Emirati culture. The current state of the fisheries presents a major challenge to the UAE, in ensuring that this resource upon which the country has depended for its survival, remains for future generations.

Other social and economic impacts include: jeopardising fisheries' contribution to future food security; lost opportunities for employment in the fishing sector; and lost recreational value and tourism opportunities.

Environmental impacts include a reduction in ecosystem function, which may have far-reaching effects on Abu Dhabi Emirate's maritime domain.

9.4 Responses

Pursuing International Best Practice in Fisheries Management

In response to the state of the fisheries, an internationally benchmarked suite of management measures has been implemented in Abu Dhabi Emirate. This has been informed by comprehensive fisheries resources assessments and scientific studies completed by EAD and others over the past 15 years.

EAD has:

- Introduced a licensing system for commercial and recreational fisheries and implemented a commercial fishing effort cap to prevent expansion and over-exploitation of the fishery (2002) [18].
- Established a representative network of Marine Protected Areas with no-take zones where fishing is prohibited (ongoing since 2004) [19].
- Regulated gear use, including limitations on the number and design of fishing gear used, specifically:
  - Gargoor have been limited to 125 traps *per* lansh and banned on tarad since 2003 [20].
  - An escape panel was made mandatory on gargoors to prevent 'ghost fishing' and the catch of juveniles (2003) [21].
- Unsustainable fishing techniques have been banned, including trawling (1980), drift netting and the use of monofilament in nets (1999) [22].
- Implemented seasonal bans to protect fish during their reproductive cycles (e.g. Kingfish and Badah (Long-tailed Silver Biddy – *Gerre longirostris*)) [23].
- Declared minimum size limits for key species (in conjunction with federal partners) (2015) [24].

Al hadhra locations were designated and information management systems supporting gargoor exchange were developed.

Enforcement was strengthened in Marine Protected Areas through the use of modern technology, with the development, in 2015, of a marine violations management and reporting smartphone application for rangers to use in the field. Alongside enforcement partners, the Critical Infrastructure and Coastal Protection Authority (CICPA), EAD continues to engage regularly with the industry and share knowledge on environmental concerns to aid in the effective enforcement of fisheries regulations.

In addition, since 2005, fishers in the emirate have been involved in the management of fisheries through the Fishing Organising Committee, with co-management established within traditional buhoor (family customary tenure) areas [25].

Abu Dhabi Fisheries Sector Review

Despite striving to achieve best practice in fisheries management, the Emirate of Abu Dhabi's fisheries continued to decline. In recognition of this, EAD completed an Abu Dhabi Fisheries Sector Review in 2014. One of the review's key recommendations was to pursue fisheries management at a federal and regional level, acknowledging that, for the Arabian Gulf fishery, a federal approach in a continuous body of water shared by other resource users was fundamental to achieving a sustainable fishery.

UAE Sustainable Fisheries Programme

In 2015, EAD and strategic partner MOCCAE joined forces to establish the strategic UAE Sustainable Fisheries Programme (UAESFP) (2015-2018). This comprehensive four-year plan featured a vision of 'Sustainable Fisheries for the United Arab Emirates' and the desired outcome of an environmentally sustainable, economically viable, socially responsible fishing sector [26].

The programme is a strategic priority and incorporates international (Aichi) and national targets: the environmental target is for 70 % of fisheries resources to be sustainably harvested above the 30 % Sustainable Catch Index threshold by 2021 [27]. The nine-project programme includes specific projects on: Fisheries Science; Fisheries Resources Assessment; Fisheries Socio-economics; Traditional Fishing Knowledge; Monitoring, Control and Enforcement; Stakeholder Engagement; Law and Policy; Fisheries Management Planning; and Information Management.

In 2015, one of the programme's first steps was to complete a UAE Fisheries Sector review which gathered all relevant scientific, legal, governance, enforcement and socio-economic data for the UAE fishery. This information identified where improvements could be made within the fisheries sector, which were to be prioritised through the UAESFP.

In addition to the sector review, the key 2015 UAESFP strategy outcomes were: the development of a National Fisheries Research and Monitoring Plan; planning for a comprehensive Fisheries Resources Assessment Survey of the UAE, which commenced in 2016; completing a UAE-wide socio-economic and traditional fishing knowledge survey; assessing monitoring control and surveillance needs; the development of proposed legislation to manage the recreational fishery; and assessment of future management options for the UAE commercial fishery.

The launch of the UAE Sustainable Fisheries Programme, which aims to create a sustainable, viable fishing sector

Ongoing research and monitoring programmes inform the fisheries strategy

9.5 Outlook

In Abu Dhabi Emirate and the wider UAE, the fishery is at a critical ecological tipping point. The ecosystem cannot sustain 2015 levels of fishing pressure (which was recorded at five times more than the sustainable level), in addition to other anthropogenic and climate change pressures (which are predicted to decrease catches by 26 % by 2090). Already, key demersal species are within the severely over-exploited category.

Following the launch of the UAESFP in 2015, there is an opportunity to reverse this decline and put Abu Dhabi Emirate's fisheries on the path to recovery and sustainable utilisation.

Changing Course

Expert opinion indicates that the fisheries will either collapse or recover, depending on decisions regarding fisheries management measures yet to be implemented.

Populations of the iconic Hamour are at just 4.7 % of the species' virgin biomass

In an un-fished scenario, it will take a species an entire life cycle before recovery occurs. Therefore, changes in fish populations, whether positive or negative, are often realised after decades.

Three possible future scenarios for Abu Dhabi Emirate's fisheries (which are dependent on three different management responses) are outlined below:

Scenario 1: Maintaining the status quo.
Retaining existing levels of fishing pressure (at five times the sustainable limit), in addition to other pressures, will likely result in further declines in the status of the fishery within the next five years and likely eventual collapse, with corresponding adverse social and economic effects.

Scenario 2: Implementing some fisheries management measures but not enough to reduce fishing pressure to a sustainable exploitation rate.
Implementing a Fisheries Management Plan which does not reduce fishing pressure by the equivalent 2015 level of over-exploitation (i.e. reducing fishing pressure by five times, which is the current over-exploitation rate), will likely result in the continuation of a severely over-exploited fishery with declines in status over a longer period (10 years) and likely eventual collapse, with corresponding adverse social and economic effects.

Scenario 3: Implementing a Fisheries Management Plan with a clear fisheries pressure reduction target equivalent to the current level of over-exploitation (which, according to 2015 figures is five times what is sustainable).
Reducing fishing pressure (using a range of fisheries management tools) by at least the amount the fishery is over-exploited will likely result in the fishery recovering, and the achievement of a sustainable fishery by the year 2030.

FORESTRY

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KEY MESSAGES

DRIVERS

Urban and infrastructure developments are increasingly putting enormous pressure on the sustainability of Abu Dhabi Emirate's forest legacy.

PRESSURES

Since forests in the emirate are artificial and dependent on human intervention, they face different pressures than natural forests elsewhere, including groundwater depletion, finance and cultural heritage.

STATE

Forests currently cover 3.5 % of the emirate. They include 20 million tree species and over 55,000 ungulates (both native and non-native). Of the forests, 79 % are classified as being in good condition.

IMPACTS

Groundwater depletion affects 21 % of forests in Abu Dhabi Emirate due to the deterioration of groundwater quantity and salinity.

RESPONSES

The classification and prioritisation of forests will ensure they can be managed scientifically and reduce their carbon footprint. Plans to optimise forestry areas in Abu Dhabi Emirate are in place, including accurate measurement of groundwater consumption using the crop calculator tool.

10 Introduction

KEY INDICATOR OF CURRENT STATE: **12.6 %** REDUCTION OF ALL WATER USE IN FORESTRY IN 2016

Forests in Abu Dhabi Emirate are mostly irrigated using non-renewable groundwater

"They used to say agriculture has no future, but with God's blessing and our determination, we have succeeded in transforming the desert into a green land"

SHEIKH ZAYED BIN SULTAN AL NAHYAN, FIRST PRESIDENT OF THE UNITED ARAB EMIRATES FROM 1971 TO 2004 AND RULER OF ABU DHABI FROM 1966 TO 2004

The Emirate of Abu Dhabi contains more than 540 afforested areas. With an area of 242,000 ha., these forests cover 3.5 % of the emirate's mainland, equivalent to 26 times the area of Abu Dhabi Island (see Map 10.1).

Abu Dhabi Emirate's forests are planted with 20 million trees, of which 88 % are native species. The forests provide shelter for both native and non-native wildlife species.

Many of these forests were planted as part of the Late Sheikh Zayed bin Sultan Al Nahyan's 'Greening the Desert' programme. This was designed to improve the quality of life for those living and working in Abu Dhabi, to protect infrastructure and to create habitat for wildlife.

Forestry in the Emirate of Abu Dhabi is mostly irrigated using groundwater. Forests are the second-largest consumer of groundwater after agriculture, using 16 % of the available groundwater budget. In Abu Dhabi, groundwater is a non-renewable resource. Only around 5 % of the groundwater that is used annually is recharged through the movement of groundwater from Oman and, to a very limited extent, rainfall. At the current rates of abstraction, the emirate's usable groundwater (fresh and brackish water) may only last for around 50 years.

Abu Dhabi Emirate has a limited groundwater reserve (see Chapter 5 – Water Resources) of which 18 % is brackish and usable for agriculture, forestry and other purposes. As a result, the emirate faces a significant challenge that threatens water security, food security, and native species of plants and animals, as well as the sustainability of its cultural legacy of forests. In addition to these challenges, forests in Abu Dhabi Emirate are facing significant risks caused by the increase in demand for suitable land for urbanisation projects and infrastructure upgrades.

To cope with these challenges, the Government of Abu Dhabi has developed a strategy for managing its forests in such a way as to ensure their long-term financial and environmental viability, while respecting and conserving forestry's natural and cultural legacy. To achieve these aims, a number of policies and programmes target issues such as optimising groundwater use, use of energy resources, non-native plants, wildlife population management, and diversifying public uses of forests.

10.1 State

Forests Details (number, area and distribution)

Abu Dhabi Emirate currently has 540 forested areas [1]. These cover 242,000 ha., comprising 3.5 % of the emirate's main land area. Of these 540 forested areas, there are 322 forests, 55 road belts, 73 farms and 44 asset plantations (see Map 10.1).

Vegetation State

Forests in Abu Dhabi Emirate contain approximately 20 million trees of both native and non-native species (see Figure 10.1). Native tree species represent 88 % of the total number.

Forest Condition

The condition of forests in Abu Dhabi Emirate is significantly influenced by the levels of water salinity, the properties of the soil in which the trees are grown and management practices at each site. Almost 79 % of the emirate's forests are in good condition (see Table 10.1).

Captive Wildlife Population Within Forests

The forests serve as reserves for approximately 55,000 individual animals, including 14 species of gazelle and other ungulates [1]. In general, the population of ungulates in the forests has been increasing due to a lack of proper herd management, such as sex separation to control breeding.

Abu Dhabi Emirate's forests provide shelter for over 55,000 animals, including gazelle

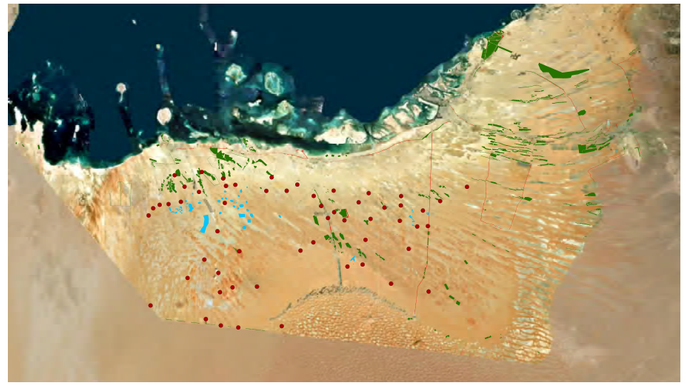
TABLE 10.1 Forest Condition for Each Area, Based on a 2015 Study

AREA	POOR	FAIR	GOOD
BAYNOUNAH AREA	0	1	50
GHAYATHI AREA	0	2	72
MADINAT ZAYED AREA	0	3	51
EASTERN AREA	4	32	133
CENTRAL AREA	5	16	41
TOTAL NUMBER	9	54	347
AREA %	7	14	79

SOURCE: EAD, 2015

MAP 10.1 Distribution of Forests in Abu Dhabi Emirate

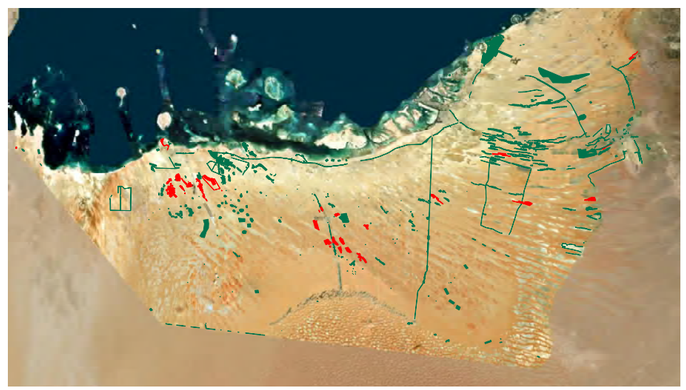
- 55 FARMS*
- ROAD BELT
- WATER RESOURCE
- FOREST



SOURCE: EAD
*DATE PALM PLANTATIONS TO SUPPORTING FREE RANGING CAMEL HERDS IN THE AL DHAFRA REGION

MAP 10.2 Distribution of Forests Holding Captive Wildlife Populations

- OTHER FORESTS
- FORESTS WITH WILDLIFE UNDER CAPTIVITY



SOURCE: EAD

FIGURE 10.1 Number of Individuals of Key Species Within Abu Dhabi Forests

DAMAS
Conocarpuss spp
972,090

PALM
Phoenix dactylifera
361,584

ARTA
Calligonum spp.
24,925

GHOWAIF
Ghowaif
430,322

SIDR
Zisiphus spina- christi
1,430,486

ARAK
Salvadora persica
6,749,822

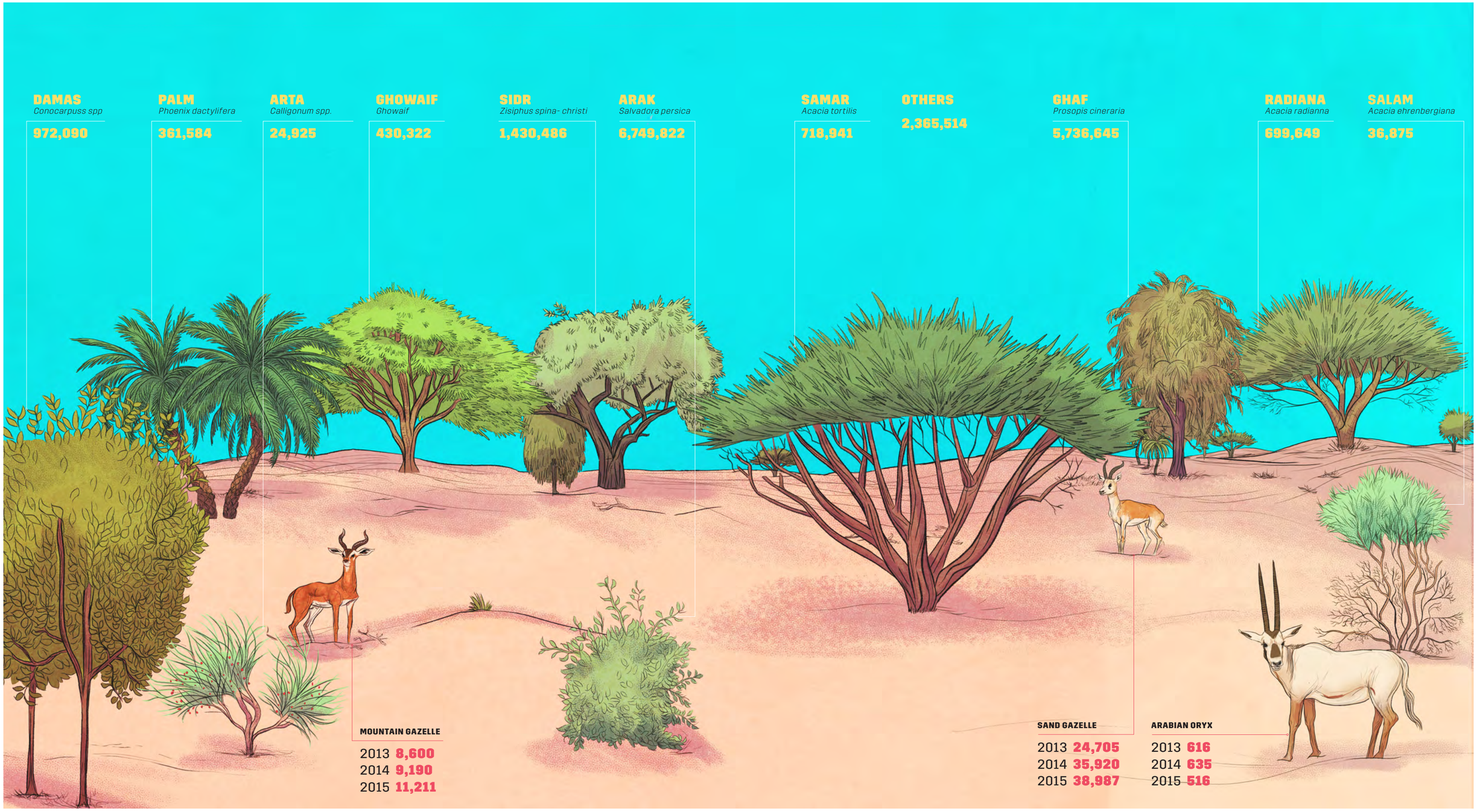
SAMAR
Acacia tortilis
718,941

OTHERS
2,365,514

GHAF
Prosopis cineraria
5,736,645

RADIANA
Acacia radianna
699,649

SALAM
Acacia ehrenbergiana
36,875



MOUNTAIN GAZELLE

2013 **8,600**
2014 **9,190**
2015 **11,211**

SAND GAZELLE

2013 **24,705**
2014 **35,920**
2015 **38,987**

ARABIAN ORYX

2013 **616**
2014 **635**
2015 **516**

SOURCE: EAD, 2015

10.2 Drivers & Pressures

Drivers

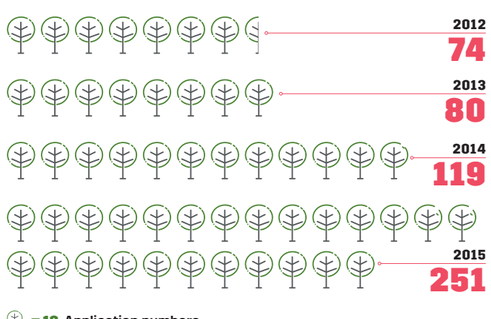
Forestry in the Emirate of Abu Dhabi first emerged during the 1970s, based on the vision of the late Sheikh Zayed bin Sultan Al Nahyan. Forests were planted artificially to protect roads and infrastructure from sand movement, act as refugia for wildlife, and enhance the urban and general landscape aesthetic of the emirate.

Although urbanisation played a key role in the emergence of forestry in Abu Dhabi Emirate, it is also affecting the long-term sustainability of the forests. The emirate is currently witnessing an increase in infrastructure development projects, which often impact forests' biotic and abiotic assets, as shown in Figure 10.2. Each application is dealt with on a case-by-case basis and the existing condition and value of the forests impacted are taken into account.

Pressures

Forests in Abu Dhabi Emirate face a variety of pressures related to the geographical location of the UAE and its associated arid climate. These pressures can be summarised as follows:

FIGURE 10.2 Projects Affecting Forestry in Abu Dhabi Emirate



SOURCE: EAD

Pressure from Groundwater Depletion

The emirate's forests are located in a hyper-arid region where annual evapotranspiration exceeds 1,900 mm/yr and rainfall is less than 60 mm/yr [2]. With the extraction of groundwater exceeding the recharge of aquifers (see Chapter 5 – Water Resources), groundwater levels are dropping, and in some areas this change is dramatic. In addition, the salinity of groundwater is increasing to levels that make it unsuitable for forest irrigation. Combined, these factors have a negative influence on the current status of the forests, jeopardising the future of forestry due to its heavy reliance on the use of groundwater for irrigation.

Financial Pressure

Since forests in Abu Dhabi Emirate are man-made plantations, their sustainability almost inevitably depends on continued human intervention. This imposes a financial burden on the government to allocate a not inconsiderable share of financial resources to cover the operation and maintenance needs of forests.

Cultural Pressure

The forests of Abu Dhabi were planted as part of the late Sheikh Zayed bin Sultan Al Nahyan's 'Greening the Desert' programme. This gives the emirate's forests a certain intangible cultural value, which current or future development plans must consider.

Pressure from Uncontrolled Breeding by the Captive Wildlife Population

The forests act as refugia for substantial numbers of captive wildlife, including culturally important threatened species such as the Arabian Oryx. However, the availability of animal welfare support, including supplementary feeding as well as lack of predation, has resulted in a considerable increase in numbers, putting the captive wildlife population at risk of disease outbreaks and genetic biodiversity depletion. A great deal of management effort is currently focussed on this area.

10.3 Impacts

Impacts

The forests of Abu Dhabi Emirate have both beneficial and negative impacts. However, with proper planning and management the beneficial impacts can be maximised.

Without doubt, the greatest negative impact of forestry is the use of critically scarce groundwater resources. This can be to the detriment of nearby natural vegetation that is reliant on the same resources.

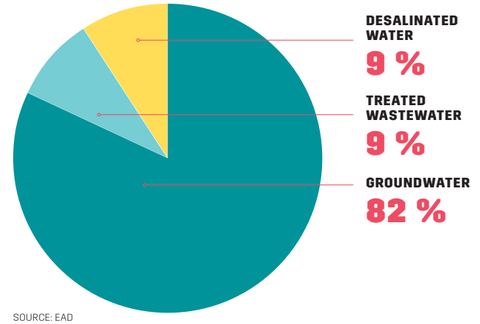
Forests provide shelter from the harsh, arid environment for both native and non-native wildlife species. It is important to find the right balance regarding forestry's negative impacts (such as depletion of water resources that impact native species) and positive impacts (such as the provision of augmented habitat that benefits native species). The following describes in more detail the negative and positive impacts associated with the forests within Abu Dhabi Emirate.

CO_2 Emissions and Green Waste

Forestry in Abu Dhabi Emirate is almost entirely dependent on human intervention. Accordingly, thousands of pieces of mechanical equipment are used to sustain the forests' vegetation, such as pumps, electrical generators and other types of machinery. While forests play an important role in regulating CO_2 levels, conversely forestry operations and maintenance are generating considerable CO_2 emissions. As such, EAD studied the amount of the emissions caused by the forests, and has already begun to implement measures to reduce some of those. In addition, there are around 64,000 tonnes of green waste produced annually from forestry operations, although the trend is to recycle this into fertiliser for further use in the forests (see Responses section below).

Sustaining the emirate's forests requires machinery including electrical pumps and generators

FIGURE 10.3 Water Types Used for Forest Irrigation in Abu Dhabi Emirate



SOURCE: EAD

Water Consumption

Annually, the forests of Abu Dhabi Emirate consume around 214 million m^3 of water. 82 % of this is groundwater, with the remainder made up equally of treated sewage effluent (TSE) and desalinated water. This makes forestry the second-largest consumer of groundwater in the emirate after agriculture. However, at the current rates of abstraction, EAD estimates that the emirate's supply of usable groundwater (fresh and brackish water) will last for less than 50 years [3].

10.4 Responses

Existing Responses

To cope with the challenges facing forestry in Abu Dhabi Emirate, the government has developed a long-term forestry strategy [4]. This aims to sustain the emirate's forestry heritage in such a way as to ensure its long-term financial and environmental viability. As such, a number of actions, initiatives, and action plans have been implemented, which include:

CO_2 Emission Reduction and Assets Electrification Programme

Despite the inevitable relationship between forestry operations and resources use, forestry management in Abu Dhabi Emirate is focused on reducing its carbon footprint. This is by shifting from the use of assets that utilise fossil fuels to electrical machines and pumps that use solar energy wherever feasible and practical.

TABLE 10.2 Classification and Evaluation of Abu Dhabi Forests

143 FORESTS	LOW VALUE
159 FORESTS	MODERATE
18 FORESTS	HIGH VALUE

SOURCE: EAD, 2015

56 forests are now connected to sources of treated sewage effluent (TSE)

Forests Database Verification

Forestry in Abu Dhabi Emirate commenced in the early 1970s. At the time forestry data was not taken into consideration. As a result, there is now a shortage of documented data for the emirate's forests. To tackle this issue, EAD has established the framework for a comprehensive Forestry Geo-database.

Forests Classification and Evaluation

EAD has implemented a comprehensive classification and evaluation programme in order to prioritise forests based upon criteria such as conservation value, role in infrastructure protection and food security. This classification system will facilitate decision-making when considering future management options for forests, including the possibility of decommissioning.

Utilising Alternative Water Resources for Irrigation

To minimise the effect of forests on Abu Dhabi Emirate's limited groundwater resources, 56 forests have been connected to sources of TSE over the last few years. It is notable that all forests irrigated by TSE show improvements in the condition of vegetation cover. This is related to the fact that TSE increases carbon storage in the soil [5].

TABLE 10.4 TSE Projects Connected to the Forests in Abu Dhabi Emirate (2009-2015)

FOREST NAME	WATER CONSUMPTION BY SOURCE (M^3/DAY)		
	TSE	WELLS	TOTAL
JABAL AL DHANNA - HOTEL FOREST	91	-	91
SALAMAT NURSERY	109	-	109
MERSHED FOREST	218	-	218
JABAL AL DHANNAH ROAD BELT	410	222	632
INTERNATIONAL ROAD TARIF 1	419	4,419	4,838
AL QATTAR FOREST	455	3,478	3,933
AL SHABHANA FOREST	910	494	1,404
SABKHA BILMALEH FOREST	1,291	-	1,291
AL RUWAIS - AL SAMRYA ROAD	1,320	4,691	6,010
AL HAFFAR FOREST	1,499	-	1,499
AL MAYDUR FOREST	8,008	4,257	12,265

SOURCE: EAD, 2015

TABLE 10.3 Number of Wells with Pumps Replaced by Electrical Pumps Between 2012-2015

ACHIEVEMENTS	POWER SOURCE	2012	2013	2014	2015	TOTAL
DIESEL PUMPS REPLACED BY ELECTRIC SUBMERSIBLE PUMPS	ELECTRIC GRID			22	79	101
DIESEL PUMPS REPLACED BY ELECTRIC SUBMERSIBLE PUMPS	1 GENERATOR POWERING MANY	110	130	150	91	481
DIESEL PUMPS REPLACED BY ELECTRIC SUBMERSIBLE PUMPS	SOLAR POWER			5	6	11
TOTAL NO. OF WELLS TRANSFORMED WITH BETTER POWER SOURCES		**110**	**130**	**177**	**176**	**593**

SOURCE: EAD, 2015

TABLE 10.5 Annual Saving in Carbon Generation Due to the Use of New Power Sources (in Kg of CO_2)

OLD POWER SOURCE	NEW POWER SOURCE	2012	2013	2014	2015	SUMMATIVE
MECHANICAL PUMPS DIESEL	ELECTRIC GRID			622,512	2,235,384	2,857,896
MECHANICAL PUMPS DIESEL	1 GENERATOR POWERING MANY	1,729,200	2,043,600	2,358,000	1,430,000	7,561,320
MECHANICAL PUMPS DIESEL	SOLAR POWER			157,200	188,640	345,840
SUMMATIVE SAVINGS		**1,729,200**	**2,043,600**	**3,137,712**	**3,854,544**	**10,765,056**

SOURCE: EAD, 2015

Captive Wildlife Population Size Management

In 2015, EAD commenced a pioneering programme for population management, capturing and translocating female gazelle from different forest sites in Abu Dhabi Emirate. The programme was initiated as a preventative response to the potential for disease outbreaks and inbreeding, and to enhance the genetic diversity of the species within the forests. In its first stage, the programme targeted the three most populated forests in the emirate. The programme will expand to include other forests in subsequent phases.

Reducing Desalinated Water Use in Forests

Abu Dhabi Government is targeting a reduction in desalinated water usage in 44 forests, with a 20 % annual reduction over a three-year time period. This action plan was started in 2015 and positive results were achieved in the first year of implementation.

Research and Crop Calculator

Experiments carried out in collaboration with the forestry management contractor between 2009 and 2015, resulted in the following:

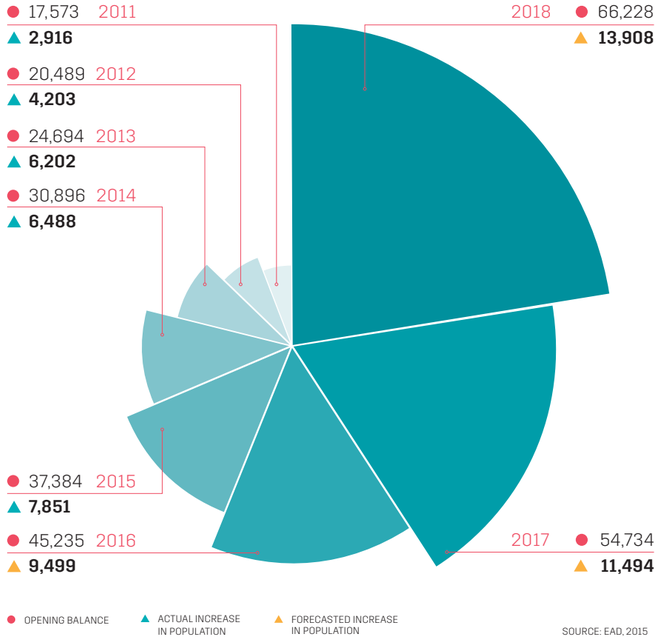
- Testing of the latest technologies related to agriculture to determine suitability for forestry.
- Testing of new irrigation systems, such as subsurface irrigation.
- Experimentation on plants to assess the capability of using water with different salinity levels.
- Pilot project to calculate water consumption by different tree species.

Recycling of Green Waste

The estimated amount of waste produced by forests in Abu Dhabi Emirate annually is 64 tonnes. To reduce the effect of this waste on the environment, Abu Dhabi Government adopted a programme to recycle this amount into compost. Currently, the total amount of compost produced is 30 tonnes *per* year.

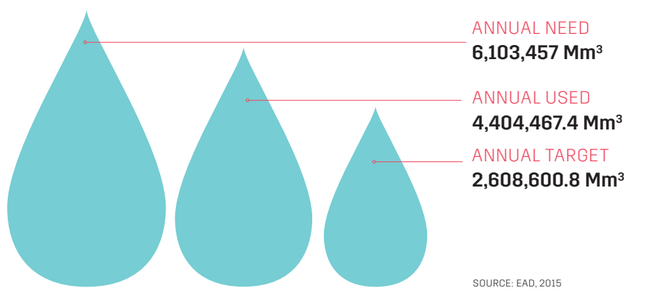
Due to EAD's population management programme, numbers of Sand Gazelle are forecast to grow by nearly 14,000 by the year 2018

FIGURE 10.4 Sand Gazelle Population Growth Projection



SOURCE: EAD, 2015

FIGURE 10.5 Reduction of Desalinated Water Uses in Al Jarf Area (Million m^3 / year)



SOURCE: EAD, 2015

10.5 Outlook

To reduce the pressure on groundwater in Abu Dhabi Emirate, 56 forests have been connected to TSE for irrigation. This has resulted in increased vegetation cover, as treated wastewater can increase carbon storage in soils. In the future, it is likely that TSE will be used increasingly for irrigation within forests, which may well have a beneficial impact in terms of future vegetation cover.

There have also been pioneering efforts to manage wildlife population size in the emirate's forests. This trend is likely to continue, to the benefit of local fauna and flora within the forests.

As management of Abu Dhabi Emirate's forests and the wildlife within them improves, so will the condition of the forests. While forestry in the emirate certainly has merit in terms of infrastructure protection, cultural heritage, amenity value and even some intrinsic value, this is currently at the expense of valuable water resources. Looking forward, it is unlikely that there will be an increase in forested areas in the emirate. However, with improved irrigation techniques and the use of alternative sources of water, such as TSE, it will be possible to reduce the demand for water within the existing forests.

Improving forestry management in Abu Dhabi Emirate also has a positive effect on native wildlife species

WASTE

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KEY MESSAGES

DRIVERS

Population growth (resulting in increasing consumption and waste), rapid economic development without a concomitant increase in waste treatment infrastructure, and consumer behaviour are key drivers of a change in the state of waste in the emirate.

PRESSURES

Currently, there is a lack of incentives and deterrents and an absence of adequate infrastructure to encourage the proper management and treatment of waste.

STATE

There is a continued increase in waste volumes and illegal dumping, reflecting the lack of appropriate infrastructure in the emirate. In 2015 the waste *per capita* was 1.65 kg/day of municipal solid waste.

IMPACTS

Current waste management practices in the emirate have an impact on energy consumption and release of emissions, and adverse impacts on human health, air quality, climate change, biodiversity, land and water.

RESPONSES

The emirate has developed a number of measures to improve waste management, including: public awareness initiatives and engagement in sustainable consumption; improved infrastructure based upon accurate data; incentive programmes to encourage waste minimisation, reuse and recycling; and enhanced, enforceable regulations. A comprehensive regulatory framework and the proposed integrated waste management master plan will also help Abu Dhabi Emirate achieve national and local targets.

11 Introduction

KEY INDICATOR OF CURRENT STATE: **1.65 KG *PER CAPITA* PER DAY OF MUNICIPAL SOLID WASTE GENERATED IN 2015**

Waste can be categorised as either hazardous or non-hazardous, and it is either disposed of or is waiting to be disposed [1]. It may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, or through other human activities.

The key challenge facing Abu Dhabi Emirate over the last few decades has been the amount of waste generated, a figure which has increased rapidly as a result of a growing population and high-consuming society. Official 2015 figures estimated that 8.48 million tonnes of waste was generated, more than 23,200 tonnes *per* day. Along with the large quantities of waste dumped at thousands of illegal sites scattered around the emirate, this poses a significant threat to the emirate's biodiversity and threatens the health of the general population [2].

More than 23,000 tonnes of waste is generated in Abu Dhabi Emirate each day

11.1 State

During the last three decades, waste management in the Emirate of Abu Dhabi was a government service provided by municipalities in Abu Dhabi, Al Ain and the Al Dhafra Region. Mixed solid waste was collected manually by labourers on a daily basis from mixed containers located in public and residential areas. In 2008, Abu Dhabi Government established Tadweer (The Center of Waste Management – Abu Dhabi) to centralise waste management operations in the emirate.

In 2015, the average person in the Emirate of Abu Dhabi produced 1.65 kg of municipal solid waste *per* day [2]. This rate is comparable to global figures.

Solid Waste

In 2015, the total amount of solid waste generated in Abu Dhabi Emirate was estimated at 8.48 million tonnes, of which 99 % was non-hazardous and 1 % was hazardous. From this total, 34 % was construction and demolition (C&D) waste, 20 % municipal waste, 39 % industrial and commercial waste, 6 % agricultural waste and 1 % from other sources. Of the total waste generated in 2015, 28 % was recycled, around 6 % was composted and 66 % was sent to landfill, dumpsites or others [2].

Radioactive Waste

In September 2009, UAE President H.H. Sheikh Khalifa bin Zayed Al Nahyan approved federal Law No. (6) of 2009. This concerned the peaceful uses of nuclear energy, and established the Federal Authority for Nuclear Regulation (FANR) as the UAE's nuclear regulatory body. FANR is responsible for regulating, controlling and licensing nuclear activities in the UAE which (in addition to the nuclear power programme) includes radioactive material and radiation sources used in medicine, research, oil exploration and other industries.

The UAE Government is developing a national strategy for radioactive waste management, fully aligned with the standards and processes set by the International Atomic Energy Agency (IAEA). This covers all forms of radioactive and nuclear waste, including waste from nuclear plants.

There are a number of ways to manage effectively the other types of radioactive waste, according to their type and source:

For radioactive sources used in industry and some of the radioactive sources used by the healthcare sector, the current mechanism is to return the waste to the supplier of the material outside the UAE. This practice is regulated in accordance with a permit issued by FANR.

Other radioactive sources in healthcare facilities are stored for a period of time to reduce their radioactivity levels to normal, so they can be treated in the same way as medical waste. These include contaminated clothing, medical tools and human waste that may have been contaminated with radioactive materials [4].

TABLE 11.1 Municipal Waste Generation

COUNTRY	WASTE PRODUCED (KG/CAPITA/DAY)
OECD	2.2
USA	2.04
ABU DHABI	1.65
UK	1.32

SOURCE: SCAD [2], EAD [3]

Hazardous Waste

Hazardous waste is defined as waste with properties that make it dangerous or potentially harmful to human health or the environment. Hazardous wastes can include liquids, solids, contained gases or sludge. They can be by-products of manufacturing processes or simply discarded commercial products, like cleaning fluids or pesticides. Hazardous waste is generated from different sources including industry (non-oil and gas, and oil and gas industries) and healthcare facilities. The emirate's hazardous solid wastes totalled 57,500 tonnes in 2015 [2].

Waste operations in the emirate are managed by Tadweer

Illegal Dumping

Today, illegal dumping in Abu Dhabi Emirate remains a challenge. This is defined as the disposal of waste in a manner contrary to environmental laws and waste management in the Emirate of Abu Dhabi. EAD worked closely with Bayanat (a national company for the provision of mapping, surveying and geospatial services), to survey and identify illegal dumpsites in the emirate (see Map 11.1). The findings showed a startling 32 % increase in the number of sites [5]. EAD is collaborating with Tadweer on a plan for the clean-up and remediation of these sites. In addition, they are developing the necessary framework to prevent this phenomenon in the future.

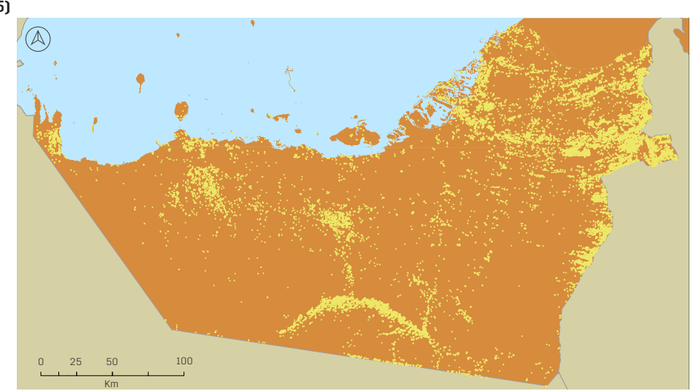
Regulatory Framework

Currently, EAD is the competent authority in charge of protecting the environment and regulating waste in the Emirate of Abu Dhabi. As such, it is responsible for the development of policies, regulations and guidelines aimed at protecting the environment and for managing the life cycle of regulations born from environmental protection policies [6].

EAD is mandated to study and understand the environment. This includes (but is not limited to): monitoring the emirate's air, water, soil, habitats, wildlife and flora. The monitoring data is analysed and used for decision-making purposes and regulation development.

MAP 11.1 Illegal Waste Dump Sites (2015)

DUMP SITES



SOURCE: EAD

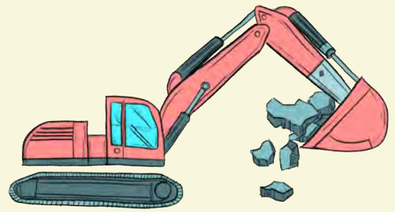
FIGURE 11.1 Total Waste in Abu Dhabi Emirate in 2015

APPROXIMATE BREAKDOWN

8.42

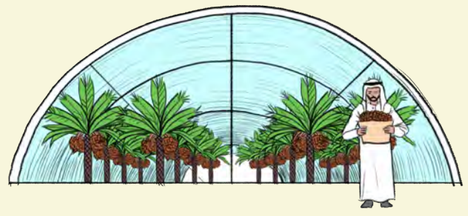
MILLION TONNES OF NON-HAZARDOUS WASTE PRODUCED

39 %
INDUSTRIAL AND COMMERCIAL WASTE



34 %
CONSTRUCTION AND DEMOLITION WASTE

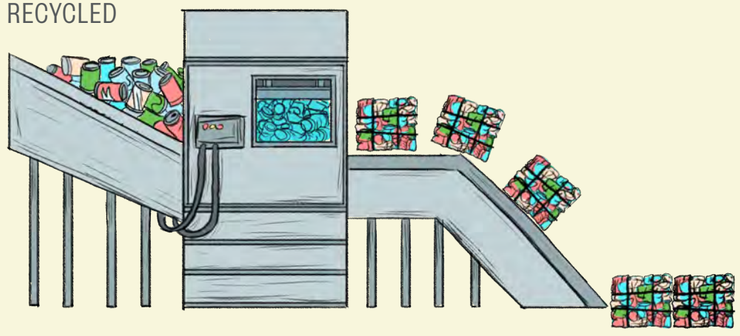
20 %
MUNICIPAL WASTE



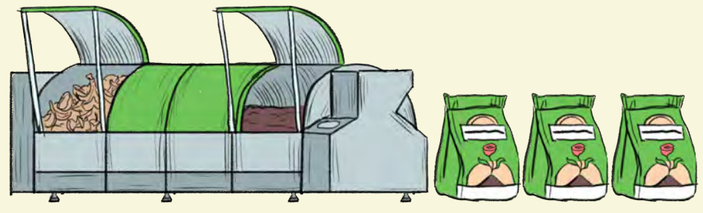
6 %
AGRICULTURAL WASTE

1 %
OTHER

66 %
LANDFILL, DUMPSITES OR OTHERS



28 %
RECYCLED



6 %
COMPOSTED

TOTAL WASTE PRODUCED

8.48 MILLION TONNES
OF SOLID WASTE PRODUCED

99 %
8.42 MILLION TONNES
of non-hazardous waste

1 %
0.06 MILLION TONNES
of hazardous waste

SOURCE: SCAD [2]

EAD is responsible for raising awareness and educating stakeholders about key environmental issues and for collecting feedback from stakeholders. The laws establishing and delineating the relevant authorities are as follows:

- Law No. (21) of 2005 for Waste Management in the Emirate of Abu Dhabi empowers EAD with a supervisory and regulatory role
- Law No. (17) of 2008 establishes The Center of Waste Management – Abu Dhabi (Tadweer) and entrusts it with a management role

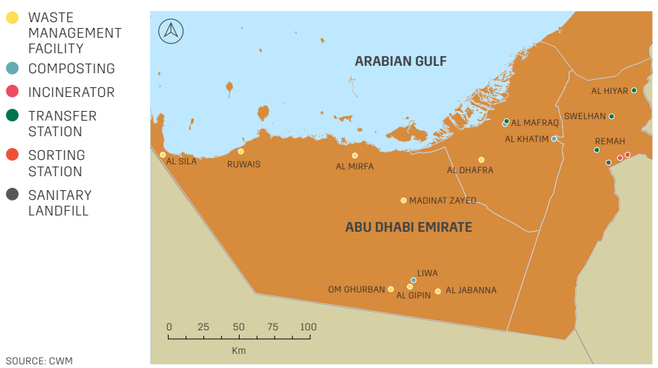
Even though EAD is the competent authority on waste management in the Emirate of Abu Dhabi, waste management responsibilities are split among the following institutions: Tadweer (municipal solid, commercial, medical, agricultural, industrial, construction and demolition); ADNOC (oil and gas); FANR (radioactive). This division of responsibility presents a challenge when it comes to developing regulations and enforcement. Furthermore, there is a lack of standardisation across the UAE (such as the diversion of waste to emirates with the lowest regulatory standards and lowest level of regulatory supervision, and consequently, the cheapest disposal tracks).

EAD and the concerned authorities continue to work on collaborative approaches to minimise potential gaps and conflicts.

The Regulation and Supervision Bureau (RSB) was established under Law No. (2) of 1998 and is considered the independent regulator of the water, wastewater and electricity sectors in the Emirate of Abu Dhabi. RSB has exclusive authority to regulate all companies undertaking activities associated with electricity and water production, transmission, distribution and supply. In addition, RSB regulates the domestic wastewater sector, which is responsible for ensuring the safe collection, treatment and disposal of wastewater products.

Law No. (17) of 2005 established Abu Dhabi Sewerage Services Company (ADSSC) as a public joint stock company to undertake all activities and tasks related to sewerage services, as mentioned in Law No. (2) of 1998, and as amended by Law No. (19) of 2007. As *per* the law, the company owns all sewerage service utilities and facilities, including the sewerage network, pipelines and pumping stations in the emirate, which were owned by the Department of Urban Planning and Municipalities (DUPM). The company also has responsibility for the collection, treatment, disposal and recycling of sewerage, and the maintenance and development of sewerage services utilities and facilities in the emirate.

MAP 11.2 Abu Dhabi Waste Management Facilities



SOURCE: CWM

Technology and Infrastructure Capacity

Despite the waste collection efforts and programmes carried out by Tadweer, there are still many challenges in the waste management sector. The waste management infrastructure capacity of Abu Dhabi Emirate has not been upgraded to match the increase in waste generation. In addition, the current treatment and disposal methods (landfilling) are inadequate from an environmental perspective. The lack of segregation at source and lack of availability of recycling facilities pose a challenge to achieving diversion from landfill targets.

Finally, the limited capacity of hazardous waste treatment facilities and the lack of presence of a hazardous waste disposal facility in the emirate pose a challenge, both to generators (mainly industry) and to Tadweer [7, 8, 9]. Generators currently must send their waste to treatment facilities (through environmental service providers), which results in increased emissions from transporting the hazardous material, with an increased risk of spills or release to the environment [7, 8, 9]. Some generators, faced with the lack of alternatives, end up illegally disposing of waste, putting a burden on Tadweer and posing major risks to the environment and to human health.
Waste generated in the Emirate of Abu Dhabi is disposed of in nine controlled dumpsites and one sanitary landfill. Table 11.2 shows a detailed list of existing waste management facilities and their respective capacities.

TABLE 11.2 Existing Waste Management Facilities in the Emirate of Abu Dhabi

NAME & LOCATION OF WASTE FACILITY	CAPACITY WASTE PRODUCED
TRANSFER STATION, AL AIN	NOT AVAILABLE
MEDICAL WASTE INCINERATOR, AL AIN	TWO LINES WITH OPERATIONAL CAPACITY OF ABOUT 200 KG/HOUR EACH
FALLEN STOCK INCINERATOR, AL AIN	TWO LINES WITH DESIGN CAPACITY OF ABOUT 650 KG/HOUR EACH
SANITARY LANDFILL, AL AIN	NOT APPLICABLE
C & D WASTE CRUSHER PLANT, AL AIN	2,000 TONNES/DAY
TYRE RECYCLING PLANT, AL AIN (GULF RUBBER FACTORY LLC)	ABOUT 6.3 TONNES/HOUR
PLASTIC RECYCLING PLANT, AL AIN	HIGH DENSITY LINE WITH A THROUGHPUT OF 1 TONNES/HOUR AND LOW DENSITY WITH A THROUGHPUT OF 0.4 TONNES/HOUR
SORTING STATION, AL AIN	1,000 TO 1,200 TONNES/DAY
COMPOST PLANT, AL AIN	400 TONNES/DAY
CONTROLLED DUMP SITE, AL AIN	NOT APPLICABLE
USED OIL RECYCLING PLANT, ABU DHABI	1,500 LITRES/HOUR
TRANSFER STATION, AL MAFRAQ	NOT AVAILABLE
AL DAFRAH DUMPSITE, ABU DHABI	NOT APPLICABLE
COMPOST PLANT, AL MAFRAQ COMPOST PLANT, AL KHATIM COMPOST PLANT, LIWA	COMBINED DESIGNED CAPACITY OF ABOUT 100,000 TONNES/ANNUM
CONTROLLED DUMP SITE, AL DHAFRA REGION SILA DUMP SITE MARFA DUMPSITE RUWAIS DUMPSITE MEDINA ZAYED DUMPSITE LIWA/AL JIFN LIWA/AL JABBANA LIWA/UM AL GHURBAN (ARADA)	NOT APPLICABLE
C & D WASTE CRUSHER PLANT, AL DHAFRAH – ABU DHABI	8,000 TONNES/DAY

SOURCE: TADWEER, 2016 [7]

Wastewater and Biosolids

The total number of sewage treatment plants (STPs) increased from 12 in the 1990s to 30 in the last

TABLE 11.3 Number of STPs and Design Capacities

CRITERIA	2012	2013	2014	2015
NO. OF STPS	37	37	37	39
DESIGN CAPACITY (ML/D)	1,155	1,184	1,200	1,214

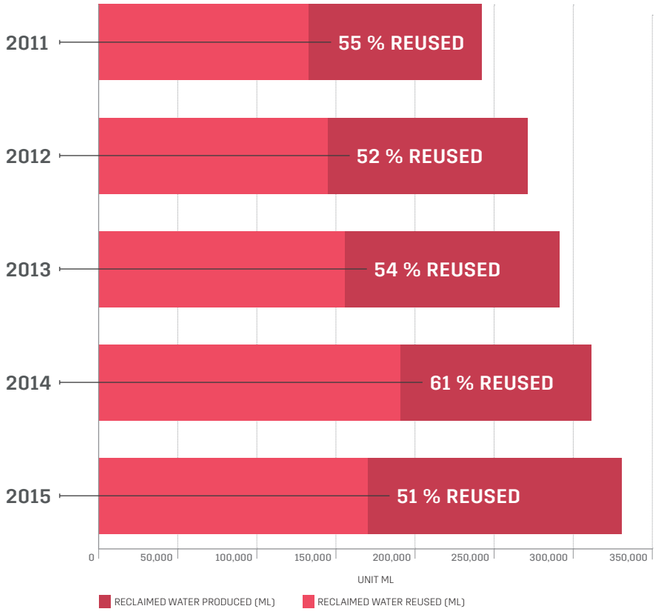
SOURCE: RSB, 2014 [11], ADSSC, 2015 [12]

TABLE 11.4 Total Annual Flow and Average Daily Flow Handled by the STPs

	2011	2012	2013	2014	2015
ANNUAL FLOW (ML)	245,359	283,107	302,425	322,681	344,389
AVERAGE DAILY FLOW (ML/D)	672	776	829	884	944

SOURCE: RSB, 2014 [11], ADSSC, 2015 [12]

FIGURE 11.2 Annual Quantities of Sewage Wastewater Treated, Reused and Disposed of in the Environment



SOURCE: EAD, 2014 [4], RSB, 2014 [11], ADSSC, 2015 [12]

decade, and 39 in 2015. The maximum volumetric treatment design capacity increased from 372.8 million litres *per* day (Ml/d)) in the 1990s to 418 Ml/d in the last decade, and 1,214 Ml/d in 2015. The total percentage increase between 2015 and the 1990s was 226 % [10].

Table 11.3 shows the change in the number of STPs and maximum volumetric treatment design capacity between 2012 and 2015 [11, 12].

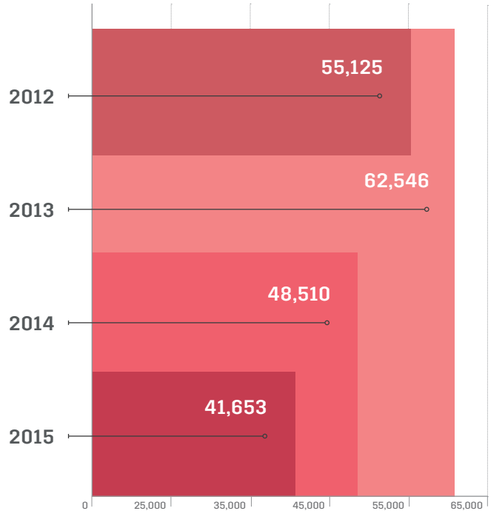
The treatment levels adopted for wastewater over the last 20 years are almost the same, with tertiary treatment technology in most of the STPs, and trickling filters in some small-scale treatment facilities. However, the technologies of sewage sludge treatment were enhanced. The main treatment during the 1990s was stabilisation only, with thickening and drying beds being used over the last 10 years [10].

Table 11.4 shows the total annual flow and average daily flow handled by the STPs between 2011 and 2015. In 2015 the treatment systems managed an annual total flow of 344,389 Ml/d with an increase of about 40 % compared to the annual flow in 2011 [11, 12].

It is noteworthy that the limited quantities of wastewater transferred by tankers is not accepted for disposal by ADSSC networks due to quality. Currently, RSB is developing tankering regulations to tackle this issue.

Figure 11.2 shows quantities of sewage wastewater treated, reused and disposed of in the environment (mainly into the marine environment) over the period 2011 to 2015. Reclaimed water uses include irrigation of amenities, agriculture and forestry irrigation [11, 12, 4].

FIGURE 11.3 Biosolids Quantities Produced (Dry Tonnes)



SOURCE: RSB, 2014 [11], ADSSC, 2015 [12]

Due to the lack of proper infrastructure, reuse percentages are considered relatively low, ranging from 51 to 61 %. However, there are plans to construct transfer trunk lines to enhance utilisation of reclaimed water.

Biosolids (sewage sludge) are a by-product of sewage treatment. The dry mass of biosolids generated from all STPs is shown in Figure 11.3. Currently, all produced quantities are transferred to landfill sites licensed by Tadweer. RSB plans to adopt policies and initiatives to encourage the use of biosolids for various beneficial uses, particularly for agriculture [11, 12].

Outreach and Communication

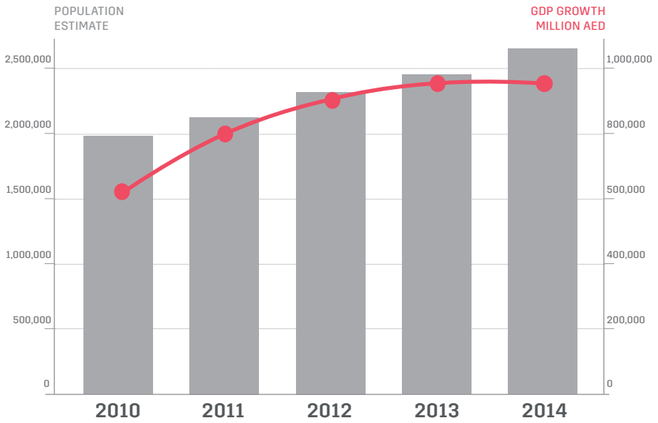
In 2010 the level of awareness on waste management-related issues among residents of Abu Dhabi Emirate was 62.9 %. The figure indicates a fair understanding of waste management issues and their impact on the environment. However, the trend in waste practices in 2010 highlights that in spite of a good level of understanding of the waste impact on the environment, only a few percent of the public were taking action and adapting sustainable waste management practices. The behaviour results for waste-related issues in 2010 indicate that only 11.6 % of the public were taking active steps to reduce the number of plastic bags they used. Likewise, only 13.3 % were segregating their waste, 7.9 % were printing on both sides of paper and just 9.3 % were actively recycling at least some items [13].

In order to encourage the general population to be more environmentally responsible, over the last five years, EAD, Tadweer and a number of other relevant entities have conducted several educational and awareness activities on waste issues. These include: the Paperless Day Initiative; the Sustainable Schools and Sustainable Campus Initiatives; clean-up campaigns; the UAE Plastic Bag Free campaign; regular workshops; and the development of educational materials such as The Sustainable Waste Management For Organisations guide and waste-related infographics [14, 15, 16].

Outreach educational tools and activities had a noticeable impact on the overall level of awareness and behaviour on waste issues among the residents of Abu Dhabi Emirate. The results from 2014 indicated an increase in the level of awareness and behaviour since 2010. In 2014, the level of awareness on waste management issues increased to 70 %, with the overall level of sustainable behaviour rising to 52 % [17].

11.2 Drivers & Pressures

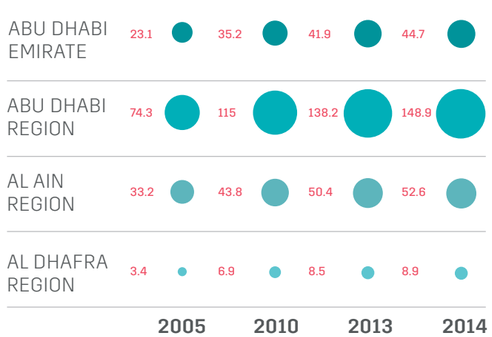
FIGURE 11.4 Gross Domestic Product (GDP) Growth and Population



SOURCE: EAD, 2016 [3]

FIGURE 11.5 Population Density Growth

PERSONS *PER* SQUARE KILOMETRE



SOURCE: EAD, 2016 [3]

Population and Economy

Population growth and economic development are the main drivers of waste generation in the Emirate of Abu Dhabi. The emirate's 2014 GDP was an estimated AED 960,146 million at current prices. This represents an annual growth rate of 3.0 % in 2014, 2.4 % in 2013 and 7.4 % in 2012, pointing to a robust and stable economy. Accordingly, the annual *per capita* GDP amounted to AED 361.4 thousand in 2014 and AED 373.8 thousand in 2013 [2].

Figure 11.4 displays the trend in population increase between 2010 and 2014, along with the GDP growth *per* year [3].

The resident population of the Emirate of Abu Dhabi was recorded at 2,656,448 people in 2014, with an annual population growth rate of 7.6 %. However, the population density in 2014 was 44.7 persons *per* square kilometre, while in 2013 there were 41.9 persons *per* square kilometre (see Figure 11.5).

Figure 11.5 shows the changes in population density of Abu Dhabi Emirate and its three regions from 2005 to 2014. It indicates a 93.5 % population growth during this period, which is one of the main drivers in waste generation increases. Abu Dhabi Region has the highest population density, while Al Dhafra Region is the most sparsely populated with a fast population growth.

11.3 Impacts

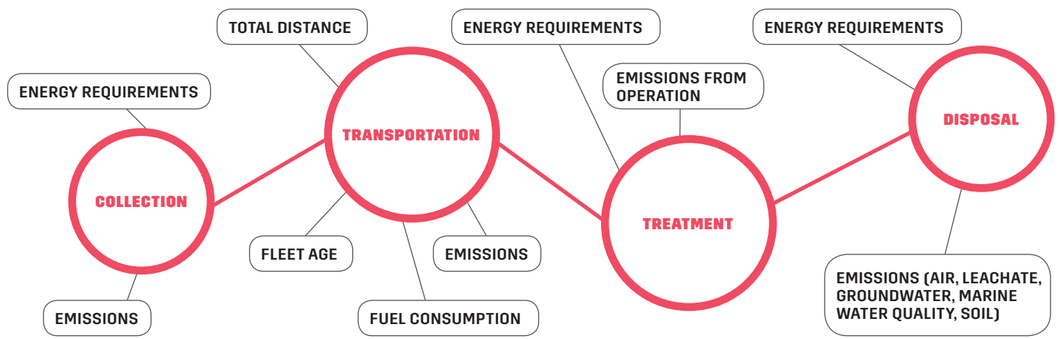
Waste management activities include the collection, transportation, treatment and disposal of waste [3, 18]. The environmental impacts associated with each of these activities include energy consumption and the release of emissions into the environment from each activity, as shown in Figure 11.6.

The current practice of disposing of the majority of waste in landfill and uncontrolled dumpsites has a potentially adverse impact on human health, due to exposure to airborne waste particulates and contamination of soil. Related health effects may range from cancer and neurological and reproductive diseases, to immune-suppressive effects. Currently, further studies are required because there is insufficient information to assess the burden of disease due to soil and groundwater contamination from uncontrolled waste disposal sites or landfill.

Based upon the current available data, waste management in the Emirate of Abu Dhabi has the following impacts on the environment:

- AIR AND CLIMATE CHANGE: Methane gas (CH_4) is released due to anaerobic decomposition of organic materials in dumpsites or landfill, causing severe odour nuisance and potential explosion hazards (CH_4 is 21 times more potent a greenhouse gas (GHG) than carbon dioxide (CO_2)). In addition, the transportation of waste to disposal sites produces GHG gases due to the combustion to fuel. GHG emissions were estimated at 700,000 tonnes of CO_2eq [20].
- BIODIVERSITY: Habitat destruction, especially in areas close to dumpsites/landfill. Animals are at risk from illegal waste and waste disposed in open dumpsites. The animals can get entrapped in the waste or die from consuming the waste.
- LAND: Because dumpsites are unlined, waste can be deposited on the surface where pollutants may contaminate the soil. Uncontrolled dumpsites also adversely affect the landscaping and land use of the immediate surroundings.
- WATER: As a result of unlined dumpsites, pollutants can leach through to the groundwater. Leachate is currently not critical at this point due to high evaporation rates.

FIGURE 11.6 Environmental Impact Consideration



SOURCE: CRC PRESS, 2016 [19]

11.4 Responses

Waste Management Strategy for the Emirate of Abu Dhabi

The high-level strategy for waste management in Abu Dhabi Emirate was developed jointly by EAD, Tadweer, FANR and ADSSC. This is inclusive of all types of waste, including those from the oil and gas sector. The strategy aims to upgrade the emirate's waste management infrastructure, operations, monitoring and funding mechanisms over the next five years [4].

Abu Dhabi Waste Policies and Guidelines

In 2015, EAD and Tadweer issued a set of policies and guidelines aiming to reinforce sustainable waste management in the Emirate of Abu Dhabi. The new policies include: waste planning; waste classification, licensing and enforcement; waste collection, segregation, transfer and tracking; waste reuse and recycling; and resource recovery, treatment and disposal. They also include a technical guideline for waste classification [21].

These policies will serve as a framework for the waste sector, and will assist EAD in its mission to create a completely integrated system that encourages recycling and reuse, reducing the waste sent to landfills. This step marks a major milestone in EAD's contribution to the Abu Dhabi Government's strategy to transform the emirate into a city that continues to meet global standards [6].

EAD and Tadweer's policies aim to create an integrated waste management system that encourages recycling and minimises waste

Hazardous Waste Management

In 2001, ADNOC built the BeAAT facility to safely manage hazardous waste generated by its operations. This facility is currently undergoing expansion of its treatment units to cater for future requirements. ADNOC also identified a need for the treatment and disposal of sludge and drill-cuttings contaminated with naturally occurring radioactive material (NORM), so new treatment units are under construction in coordination with FANR [4].

Licenses, Tariffs and Customer Service

Imposing tariffs on waste is one of the many means which has been universally adopted to reduce the volume of waste production by promoting waste reduction at its source. Tadweer has adopted a tariff system that applies to commercial and industrial sectors [3].

Behaviour Change: Paperless Day

In order to encourage the minimisation of waste, on one day each year organisations, schools and individuals commit to reducing their wasteful paper. The Paperless Day initiative has highlighted just how easy it is to make better paper-related decisions and deliver positive change within organisations, schools and the environment.

Many participants have seen the benefits of reducing wasteful paper use: as well as reducing waste, it saves money and time, and encourages a more thoughtful approach to resource use, life in general and doing business. Saving paper also reduces the impact on the environment and the population's contribution to climate change by reducing the amount of waste that goes to landfill, saving trees (forest habitats and species), and reducing water use, water and air pollution and carbon emissions [3].

In addition to the Paperless Day, other initiatives include Earth Day, clean the beach day, diving to clean, and the beach activists.

DUPM's Estidama's Pearl Rating System

Estidama, Arabic for sustainability, is an initiative developed and promoted by the DUPM. Estidama is not just a rating method or a specific action, rather it is a vision and desire to achieve a new sustainable way of life in the Arab world. The ultimate goal of Estidama is to preserve and enrich Abu Dhabi Emirate's physical and cultural identity, while creating an always-improving quality of life for its residents on four equal pillars of sustainability: environmental, economic, social and cultural. This touches all aspects of life in Abu Dhabi Emirate in order to attain a sustainable way of life, from the way construction is built and products are resourced, to the manner in which people live and choices are made.

Estidama arose from the need to properly plan, design, construct and operate sustainable developments. On one hand, this must take into account a respect for the traditions embedded within the rich local culture, with the harsh climatic nature of the region on the other. To this end, project owners, developers, design teams and even residents must think differently about how they approach design and planning processes [3].

Saving Grace

The Saving Grace Project, known locally as Hefth Al Ne'ma, is a humanitarian initiative overseen by the Red Crescent. It aims to overcome the extravagance and waste of food surpluses, redistributing them to the poor and needy with the support of ADFCA and DUPM. Since its establishment in 2005, the project has helped alleviate the suffering of thousands of needy families, orphans and workers, as well as increasing public awareness about the importance of empathy with the suffering of the disadvantaged in society. The project is divided into several sections aimed at reducing waste of food and other products, such as furniture, clothing and medicine [3].

11.5 Outlook

Looking Ahead

Waste generation in Abu Dhabi Emirate is expected to increase due to the growth of the population and economy, alongside increasing affluence. Sectoral quantities for municipal solid waste (MSW), construction and demolition waste, and hazardous and industrial waste are likely to increase by 6 %, 2 % and 7 % respectively. To establish a world-class sustainable waste management system which diverts polluting waste away from landfill disposal and maximises resource recovery properly, the UAE set two strategic targets to be achieved by all emirates by 2021 (1.5 kg MSW capita/day and 75 % of MSW generated to be treated). Also, Abu Dhabi Emirate, through the Abu Dhabi Plan, set a national target that should be achieved by 2020 (60 % of total waste generated to be treated using environmentally and economically sustainable methods).

Education and outreach projects encourage a more thoughtful approach to resource use and sustainability among the public

Regulatory Framework

Based on the five waste management policies that were developed, a set of regulatory instruments (regulations, codes of practices and guidelines) will be established. These include: permits and enforcement for waste sector; waste classification; waste reuse; waste treatment and disposal; extended producer responsibility; illegal dumping; landfills management; and waste tariffs. The development of this regulatory framework will be based on the principles depicted by the waste hierarchy and life cycle analysis (LCA). The waste hierarchy and LCA will take into account the reduction in the amount of waste generated, reuse or recycling of the waste (including resource recovery), waste treatment using best available technology, and disposal in a sanitary landfill (only when it cannot be otherwise managed). Sustainable consumption and LCA are key factors for reducing waste generation in the emirate [6].

Integrated Waste Management Master Plan

Through CWM, the Emirate of Abu Dhabi is developing an Integrated Waste Management Master Plan (IWMMP) to achieve sustainable waste management over a period of 25 years. IWMMP will cover non-hazardous solid waste, hazardous solid waste, hazardous liquid waste and recyclables [22].

IWMMP will be developed adopting an LCA approach, focusing on: the integration of activities from the point of waste generation; and collection through to the final reuse, recycling, resource recovery or disposal. It aims to put in place a proper solution for the challenges facing sustainable waste management in the emirate, such as: availability of hazardous and medical waste treatment facilities; availability of sanitary landfill for solid waste; illegal dumping of waste; and deficiencies and gaps in the availability and quality of data for proper decision-making.

IWMMP will consider different scenarios for material recovery facilities (MRF), energy from residual waste, as well as treatment of hazardous waste in a sustainable manner, evaluating these factors technologically, environmentally, financially and for versatility, to present the most preferred scenario. Strategically, the emirate will move away from landfill and will plan closure of the existing dumpsites in the long term.

Wastewater and Biosolids

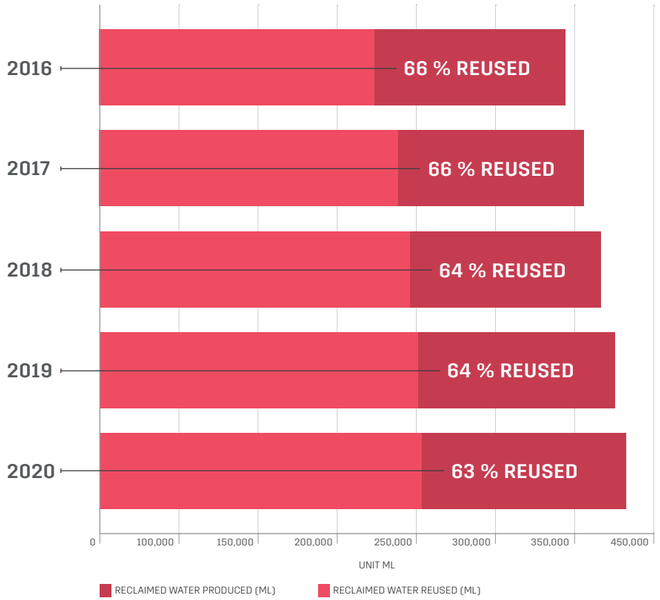
In January 2015, RSB issued Forward Plan 2015-2019, identifying priority areas and initiatives that will be undertaken to drive progress in these areas [23]. Relevant initiatives are:

- Updating regulations to facilitate social and economic development
- Improving the performance of wastewater networks
- Improving license protocols for engaging customers, connecting premises and supplying services
- Developing a robust policy for implementing more cost-reflective tariffs and supporting implementation through effective communication

The production and demand for recycled water are predicted to grow as a result of continued population and economic growth in the emirate. With the forecast population growth and the demands of future end-users, Figure 11.7 highlights the importance of identifying potential alternative reuses that will facilitate maximum utilisation. The introduction of recycled water into alternative sectors will require the development of the necessary regulatory tools, coordination with other entities and the construction of infrastructure to meet demand. Alternative sectors taken into consideration are industry and district cooling [12].

In 2015, ADSSC's Recycled Water Policy stated the emirate's vision to becoming a world leader in the provision of sewerage services by 2020. Its purpose was to demonstrate ADSSC's intent to facilitate the maximum utilisation of recycled water in a sustainable manner [12].

FIGURE 11.7 Annual Planned Reclaimed and Reused Quantities (2016-2020)



SOURCE: ADSCC, 2015 [12]

ADSSC also issued a Recycled Water Strategy, describing initiatives the company will implement in order to ensure the efficient and safe management of recycled water within the current regulatory framework [24]. The strategy sheds light on a number of initiatives, including:

- Enhancing the sewerage collection, treatment and distribution infrastructure to maximise availability of recycled water for reuse
- Establishing supply agreements for all end-user transfer points receiving recycled water
- Developing safety plans to assure the quality of recycled water
- Establishing regular quality monitoring measures and effective reporting mechanisms
- Engaging end-users to ensure that their responsibilities are identified
- Developing guidelines and codes of practice, including a recycled water use guide.

CONCLUSION

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KEY PERFORMANCE INDICATORS for the Current State of Environment in Abu Dhabi Emirate

AIR QUALITY	**76 %** OF TIME WITHIN NATIONAL AIR QUALITY LIMITS IN 2015
SOIL RESOURCES	DATA ON SUITABILITY OF LAND FOR THEIR CURRENT LAND USES WILL BE AVAILABLE IN 2020
WATER RESOURCES	**2,013 Mm^3** GROUNDWATER ABSTRACTED IN 2015 (PROJECTED VALUE)
MARINE WATER QUALITY	**94 %** OF MONITORED SITES MET GOOD MICROBIAL WATER QUALITY STANDARD IN 2015
BIODIVERSITY	**80 %** OF TERRESTRIAL AND MARINE HABITAT BASELINE AREA RETAINED IN ABU DHABI IN 2015
CLIMATE CHANGE	**40.55** TONNES/CAPITA CO_2 (BASED ON MID-YEAR REVISED 2012 POPULATION ESTIMATES PROVIDED BY SCAD)
FISHERIES	**7.6 %** OF FISH HARVESTED SUSTAINABLY IN 2015
FORESTRY	**12.6 %** REDUCTION OF ALL WATER USE IN FORESTRY IN 2016
WASTE	**1.65** KG *PER CAPITA* PER DAY OF MUNICIPAL SOLID WASTE GENERATED IN 2015

The Abu Dhabi State of Environment Report (2017) serves as an up-to-date analysis of the current status of key areas of the emirate's environment.

From air quality to fisheries, AD-SoER 2017 is a journey in understanding the various dynamic elements and relationships that Drive, put Pressure on, or Impact the environment to form what we currently observe as the State of the environment in Abu Dhabi Emirate. Our Response to this information is how our legacy will be judged by future generations.

This report provides detailed data and analysis in various important thematic chapters describing the environment, and highlights key issues of concern. This chapter is a high-level summary of all that is contained within the detailed chapters of this report.

Effective Environmental Management Requires Adequate Data and Information

In 2017, the UAE celebrated the 20th National Environment Day. This was an opportunity to take stock of where Abu Dhabi Emirate is, and to look forward to where it needs to be, in realising the vision of a more sustainable nation for current and future generations.

Twenty years ago, very little data existed on Abu Dhabi Emirate's natural environment. Over the past two decades, the Environment Agency – Abu Dhabi has collected, analysed and reported data to expand the collective knowledge on the state of the emirate's environment and the anthropogenic pressures causing environmental change. This increasing understanding is enabling the Abu Dhabi Government to develop policy responses to ensure that economic development is as sustainable as possible.

Understanding the Effectiveness of the Responses to Environmental Change Requires a More Systematic Evaluation of the Impact of Public Policy

In spite of those efforts, there is still not enough information about the drivers and impacts of environmental change on ecosystem services and public health. This is because environmental reporting has been mostly focused on understanding the pressures on, and the state of, the environment. There is also insufficient information on the effectiveness of policy responses to environmental change, as there is no requirement for a systematic evaluation of the impact of public policy.

Moving forward, we need to expand our research and our use of data and information to supply more insights on the drivers that cause environmental degradation; on the impacts of that degradation on ecosystems services and society's welfare; and, in particular, on the effectiveness of our responses to manage those impacts.

Protecting Our Environmental and Public Health Requires Leadership and Action from Government Agencies, Businesses and Individuals

Notwithstanding the advances in environmental management in the Emirate of Abu Dhabi over the last 20 years, further action is needed to address current pressures such as inefficient use of resources, and emerging challenges such as climate change. This includes more effective policies and regulations and a stronger commitment from business and individuals to embrace sustainable production and consumption.

Changes in Lifestyles, Choices of Technology and Public Policy Are Required to Reduce the Pressures Driving Environmental Change

The most important leverage points for intervention in the interactions between society and environment may not be the pressures themselves but the drivers, as they are the root causes of change.

The population of Abu Dhabi Emirate has grown very rapidly over the last few decades. This is mainly due to the influx of expatriate workers required to meet the emirate's development needs. However, a considerable number of expatriates are low-income workers, who are employed in low-skilled professions and live frugally.

Although population size and other demographic variables influence the use of food, materials, land, water, energy and transport, the impact on consumption may be less important than increasing income, culture, technology and public policy, all of which have a greater influence on what and how much people consume. Moving forward, we need to expand our research in order to understand better how those different factors may affect demand. The scant available evidence shows that public policy could be a key driver for demand. For example, *per capita* consumption of water is almost twice as large in the emirate's population segments that do not pay for it.

The Concentration of Population and Economic Activities in Coastal Spaces is Contributing to Loss of Essential Habitats

More than 60 % of the population of Abu Dhabi Emirate resides in urban centres, close to the coast and in Al Ain. The phenomenon of 'coastalisation' (i.e. the concentration of population and economic activities in coastal spaces) involves the spread of settlements along the coastline, affecting essential habitats and

wildlife. Climate change will have a major impact on the emirate's coasts, particularly through sea level rise, exacerbating coastal vulnerability.

Available Evidence Indicates a Strong Correlation Between Economic Growth and Environmental Change

A variety of studies demonstrate that income strongly influences what and how much people consume. This is also the case in Abu Dhabi Emirate, where the latest greenhouse gas (GHG) inventory found a high correlation between the growth of Gross Domestic Product (GDP) and carbon emissions.

Carbon Footprint is the Largest Component of the UAE's Ecological Footprint

Due to its hot, arid climate, the UAE requires substantial quantities of energy for cooling and for the desalination of seawater for domestic water supplies. These activities are major contributors to the emirate's ecological footprint, alongside a high level of individual consumption among the population.

Households are the Greatest Contributors to the UAE's Ecological Footprint, More Than Businesses and Government

Households account for 57 % of the UAE's ecological footprint, followed by the business/industry and government sectors, which account for 30 % and 12 % respectively.

While Environmental Awareness is Improving, There is Not Enough Information on How This is Affecting Behaviour Change

Recent data from the Government of Abu Dhabi shows improvement in the level of environmental awareness of the local population. However, there is no data on how this increased awareness affects behavioural change.

While Most Air Pollutants Are Within the Limits Set in the UAE Air Quality Standard, Particulate Matter and Ozone Frequently Exceed the National Standard Limit Values

The state of ambient air quality across the Emirate of Abu Dhabi is constantly monitored through an extensive network of monitoring stations. The pollutants of major concern are particulate matter (PM_{10} and $PM_{2.5}$) and ozone, which frequently exceed the national standard limit values. Other air pollutants are within the limits set in the UAE air quality standard. Considering a business-as-usual scenario, and taking into consideration population and economic growth, concentrations of air pollutant emissions are expected to increase.

Background levels of PM_{10} are significantly high due to the emirate's arid climate. Concentrations increase when dust events occur, accounting for the high concentrations of PM_{10}. Anthropogenic sources also contribute a substantial amount, particularly to $PM_{2.5}$, with preliminary scientific studies indicating that a significant percentage of its precursors comes from sources such as road traffic, shipping and industry. At present, the UAE has not set standards for $PM_{2.5}$; however Abu Dhabi Emirate is conducting studies to support the development of a national standard and a reduction in $PM_{2.5}$ concentrations.

Abu Dhabi Government is working on a cross-sector response to improve air quality and is increasing efforts to achieve 2021 targets.

Natural Threats to Soil (Including Salinity, Erosion and Low Fertility) Combined with Anthropogenic Pressures (Such as Over-grazing and Inappropriate Irrigation) are Increasingly Affecting Agriculture

More than 85 % of land in Abu Dhabi Emirate is naturally degraded. Soil salinity, soil erosion, shallow hardpans and low soil fertility are limiting agriculture. The Soil Survey revealed that less than 6 % of the

surveyed area is highly to moderately suitable for irrigated agriculture.

In addition, there are anthropogenic pressures on soils, such as over-grazing and inappropriate irrigation. However, there is no available information on the state of soils affected by anthropogenic degradation factors such as contamination from saline irrigated water, fertilisers, pesticides and oil. More than 8,000 farms in Abu Dhabi Emirate are abandoned or nearly abandoned because of salinisation of both soil and water due to irrigation with saline groundwater.

Abu Dhabi Emirate is conducting a Soil Salinity Inventory Project over a three-year period to enhance its soil database, in order to provide decision-makers with up-to-date and accurate data to help sustain the emirate's agricultural and food sector.

Groundwater Resources are Declining Both in Quantity and Quality in Many Areas Due to Irrigation for Agriculture and Forestry

The state of groundwater quantity and quality across the Emirate of Abu Dhabi is monitored through an extensive network of monitoring stations. Useable groundwater in the emirate is limited and most of it is too saline for direct use.

Between 2005 and 2016, overall groundwater levels experienced a steady decline, particularly in the Al Ain Region. This was mainly due to high groundwater withdrawal activities, resulting in 'red zones'.

Groundwater extraction exceeds the natural recharge rate in most regions of the emirate. If current rates of extraction continue, usable groundwater reserves will decline over the next few decades. This will not only limit agriculture but will accelerate the population decline of many native species of flora and fauna.

The new Groundwater Law No. (5) of 2016 is expected to provide incentives to conserve and use groundwater more efficiently.

Reliance on Seawater Desalination to Meet Water Needs is Affecting Air Quality, Climate Change, Marine Water Quality and Biodiversity

Renewable fresh water resources in Abu Dhabi Emirate are far below the water scarcity threshold required to meet basic needs. Seawater desalination has enabled the emirate to grow well above the limitations imposed by its water scarcity.

However, current water consumption patterns do not reflect this scarcity. The emirate has one of the

world's highest rates of domestic water consumption, due mainly to outdoor uses. This has high financial and environmental costs resulting from desalination and wastewater treatment. Burning fossil fuels to desalinate water exacerbates GHG emissions, climate change and ocean acidification, while discarding brine into marine waters affects marine water quality.

Abu Dhabi Emirate has adopted an integrated water management framework to address the issues affecting water. New regulations affecting tariffs will provide incentives to conserve and use desalinated water more efficiently.

Marine Water Quality is Good but There is a Trend for Increasing Eutrophication from Coastal Industry and Treated Wastewater Discharges

The state of marine water quality across the Emirate of Abu Dhabi is monitored through a network of monitoring stations. The condition of the emirate's marine waters is generally good; however the main issue is increasing levels of eutrophication.

Salinity and temperature are also gradually increasing. These two parameters provide good proof of the inextricable interconnectivity of environmental issues, of which we need to be cognisant. The increased production of desalinated seawater to meet the growing demand is affecting the quality of marine waters. GHG emissions from the combustion of fossil fuels in power and water plants contribute to ocean acidification, accelerating coral bleaching and decreasing the rate and amount of calcification among many marine organisms. Discharges of brine from water plants also increase the salinity and temperature of marine water. Combined, these pressures are increasing the vulnerability of marine biodiversity.

The implementation of new ambient marine water quality limits will help reduce eutrophication. Simultaneously, the Abu Dhabi Government is exploring new technologies to reduce GHG emissions and brine discharges into the environment.

Biodiversity is in Decline Due to Pressures from Climate Change and Rapid Industrial and Urban Development

Development activities along the coast for residential, industrial and commercial purposes are leading to habitat loss and degradation.

Many terrestrial ecosystems are under various degrees of threat, due to significant transformation from their original extent.

Populations of some key species are stable, many have declined. Of the total known species in the emirate, less than 2 % are classified as 'threatened'. However, a much higher percentage could be considered 'vulnerable'.

Current and expected climate change impacts, such as rising temperatures and sea level, ocean acidification, frequent extreme weather events and changing patterns of rainfall and drought, will affect ecosystems and species' ability to adapt, and as a consequence this increases the loss of biodiversity. Increasing positive seawater temperature anomalies due to the combined effect of brine discharge and global warming have already had a devastating impact on coral reefs in Abu Dhabi Emirate through coral bleaching, which could have a knock-on effect on other biota.

Monitoring, reintroduction programmes and an extensive network of Protected Areas (covering nearly 29 % of the emirate's terrestrial and marine biomes) are leading to a change in the status of some of the most threatened species.

Located in an Arid Region, Abu Dhabi Emirate is Particularly Vulnerable to Climate Change

The Emirate of Abu Dhabi is already experiencing the effects of climate change, with increases in air and sea temperatures, sea level rise, higher seawater pH and salinity, as well as reduced precipitation.

Earlier concerns regarding the effect on the climate of ozone-depleting substances have diminished due to effective regulatory controls and awareness. However, there are new concerns about the effect of GHG emissions from power and fuel production, road transport, metal production and other manufacturing industries, and waste disposal sectors.

Future climatic projections for the mid- to end of the century in the Gulf region found that: rainfall will likely increase; temperature will likely increase by between 1 and 3°C; extreme weather events such as cyclones will take place; salinity will both decrease and increase depending on location; and sea level will rise throughout the Gulf.

To mitigate climate change, major efforts to use energy more efficiently and shift towards low-carbon energy sources are urgently needed both globally and locally. Major efforts to protect natural coastal systems are also required, as they can provide important benefits to help build resilience and adapt to climate change.

The State of Fisheries in the Emirate of Abu Dhabi is Very Critical. Over-exploitation of the Fisheries Has Led to a Near Collapse of Fish Stocks for Some Key Species

The loss and degradation of key habitats and marine water quality, as well as severe over-exploitation (which, according to 2015 figures, is five times greater than a sustainable level) could result in the collapse of the emirate's fisheries.

Comprehensive work has been done to understand the reasons for the situation, which include: over-capacity in the fishing fleet, coastal development, cumulative desalination activities and pollution, as well as climate change.

A comprehensive, UAE-wide fisheries management is currently in place, known as the UAE Sustainable Fisheries Programme, targeting a sustainably utilised fishery by 2030. Natural systems need time to recover, and therefore it may take many years to observe any improvement in the state of fisheries in the emirate.

Although the Generation of Waste is Within the Global Average, the Emirate's Waste Management Infrastructure Has Not Been Upgraded to Match the Increase in Waste Generation

The generation of municipal solid waste within Abu Dhabi Emirate is within global averages. However, the emirate's waste management infrastructure capacity has not yet been upgraded to match the increase in waste generation. In addition, the current treatment and disposal methods (landfilling) are inadequate from an environmental perspective. The lack of segregation at source and the lack of availability of recycling facilities pose a challenge to achieving diversion from landfill targets.

Governance also poses some challenges, with waste management responsibilities currently split among several government entities. This division of responsibility presents a challenge when it comes to developing regulations and enforcement. Furthermore, there is a lack of standardisation regarding waste management across the seven emirates.

The inappropriate disposal of waste and illegal dumping in Abu Dhabi Emirate threaten human health and the environment by affecting air quality, soil and ground water, and contributing to climate change. Moreover, improper waste disposal leads to missing out on significant economic opportunities through reusing, recycling and producing energy from waste.

A new set of policies and guidelines was issued in 2015 to reinforce sustainable waste management.

An Integrated Waste Management Master Plan for the next 25 years is currently under development, using a life cycle analysis approach and proposing different scenarios that move away from landfill.

Forests are the Second-Largest Consumer of Groundwater After Agriculture and Will Contribute to its Depletion Unless Carefully Managed

Forests in the emirate are artificial and dependent on human intervention, mainly irrigation, for their survival. Although most forests are classified as being in 'good' condition, some of the pressures affecting their feasibility are different from those faced by natural forests.

Forests are the second-largest consumer of groundwater after agriculture. They also impose a financial burden on the government to cover operation and maintenance costs. On a positive note, forests protect infrastructure from sand and provide shelter for both native and non-native wildlife species. The new long-term forestry strategy offers the opportunity to sustain the emirate's forestry heritage while ensuring its long-term financial and environmental viability.

SUMMARY

It is only through fully understanding the various Drivers, Pressures and Impacts influencing the State of Environment in Abu Dhabi Emirate that we can develop appropriate Responses in order to maintain or improve the environment in which we live.

AD-SoER 2017 provides information and analysis to help decision-makers make informed choices and develop appropriate actions.

It is our sincere wish that the information contained herein is of use and benefit for the environment of the Emirate of Abu Dhabi and the people living here, as well as for future generations.

APPENDICES

13.1 Abbreviations

ADFCA	Abu Dhabi Food Control Authority
ADFSC	Abu Dhabi Farmers' Services Centre
ADNOC	Abu Dhabi National Oil Company
ADSSC	Abu Dhabi Sewerage Services Company
AED	(United) Arab Emirate Dirham
AGEDI	Abu Dhabi Global Environmental Data Initiative
ADWEA	Abu Dhabi Water and Electricity Authority
ADWEC	Abu Dhabi Water and Electricity Company
BAU	Business As Usual
BAU-EXEC	Extended emission control scenario
BOD	Biological Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
C&D	Construction and Demolition (waste)
$CaCO_3$	Calcium carbonate
CBD	Convention on Biological Diversity
CCRG	Climate Change Research Group
CH_4	Methane
CHC	Chlorinated Hydrocarbons
CICPA	Critical Infrastructure and Coastal Protection Authority
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on Migratory Species
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
$CO_{2\text{-eq}}$	Carbon dioxide equivalent
CWM	Center of Waste Management (Tadweer)
DALY	Disability-adjusted life-year
DUPM	Department of Urban Planning and Municipalities
DO	Dissolved Oxygen
DOT	Department of Transport
DPSIR	Drivers, Pressures, State, Impacts and Responses
DSL	Dynamic Sea Level (rise)
DSM	Demand Side Management
EAA	Executive Affairs Authority
EAD	Environment Agency – Abu Dhabi
EBSA	Ecologically and Biologically Significant Marine Area
EC	European Commission
EHS	Environment, Health & Safety
EIA	Environmental Impact Assessment
FANR	Federal Authority for Nuclear Regulation
FAO	Food and Agriculture Organization of the United Nations
F-gases	Fluorinated gases
GCC	Gulf Cooperation Council
GCM	Global Climatic Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSF	Global Soil Forum
GSM	Global System for Mobile communication
GSP	Global Soil Partnership
GVA	Gross Value Added
GWh	Gigawatt Hours
H_2S	Hydrogen Sulphide
HAAD	Health Authority – Abu Dhabi
HAB	Harmful Algal Bloom
HCAWS	Higher Committee for Water and Agriculture Strategies
HFCs	Hydrofluorocarbons
IAEA	International Atomic Energy Agency
IAS	Invasive Alien Species
IASS	Institute for Advanced Sustainability Studies
IBA	Important Bird Area
ICAD	Industrial City of Abu Dhabi
ICT	Inspection and Compliance Tool
INDC	Intended Nationally Determined Contributions
IOSEA	Indian Ocean and South-East Asia
IPCC	Intergovernmental Panel on Climate Change
IQ	Intelligence quotient
ITA	Important Turtle Areas
IUCN	International Union for Conservation of Nature
IUSS	International Union of Soil Sciences
IWMMP	Integrated Waste Management Master Plan
KISR	Kuwait Institute for Scientific Research
KIZAD	Khalifa Industrial Zone Abu Dhabi
LCA	Life Cycle Analysis
LEV	Low Emission Vehicle
LEZ	Low Emission Zone
LUCF	Land-Use Change and Forestry
MAB	Man and Biosphere
MENA region	Middle East and North Africa region
METT	Management Effectiveness Tracking Tool
MGD	Millions of Gallons per Day
mg/L	Milligrams per Litre
Ml/d	Million litres per day
MMBR	Marawah Marine Biosphere Reserve
Mm^3	Million cubic metres
MOCCAE	UAE Ministry of Climate Change and Environment
MoU	Memorandum of Understanding
MPA	Marine Protected Area
MRF	Material Recovery Facilities
Mscft	Million standard cubic feet
MSF	Multi-Stage Flash distillation
MSW	Municipal Solid Waste
MWQ	Marine Water Quality
MWQMP	MWQ Monitoring Programme
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NA	Not Available
NBSAP	National Biodiversity Strategy and Action Plan
NCAR	National Center for Atmospheric Research
NCMS	National Center of Meteorology and Seismology
NENA region	Near East and North Africa region
NORM	Naturally Occurring Radioactive Material
°C	Degrees Celsius
O_3	Ozone (tropospheric)
OECD	Organisation for Economic Co-operation and Development
PA	Protected Area
PAH	Polycyclic Aromatic Hydrocarbon
PFCs	Perfluorocarbons
pH	Potential of Hydrogen
PM	Particulate Matter
PM_{10}	Particulate Matter 10 micrometres or less in diameter
$PM_{2.5}$	Particulate Matter 2.5 micrometres or less in diameter
ppm	Parts per million
ppt	Parts per thousand
QCC	Abu Dhabi Quality and Conformity Council
RCP	Representative Concentration Pathway
ROPME	Regional Organisation for the Protection of the Marine Environment
RSB	Regulations and Supervision Bureau
SBR	Spawning Biomass per Recruit
SCAD	Statistics Centre - Abu Dhabi
SDG	Sustainable Development Goal
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
SST	Sea Surface Temperature
STEP	Strategic Tunnel Enhancement Programme
STP	Sewage Treatment Plant
TPA	Terrestrial Protected Area
TSE	Treated Sewage Effluent
TSS	Total Suspended Solids
UAE	United Arab Emirates
UAESFP	United Arab Emirates Sustainable Fisheries Programme
UAESIS	United Arab Emirates Soil Information System
UK	United Kingdom
ULSD	Ultra-Low Sulphur Diesel
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollar
USP	University of Sao Paulo
VOCs	Volatile Organic Compounds
VU	Vulnerable species
WCPA	World Commission on Protected Areas
WHO	World Health Organisation
YLL	Year of Life Lost

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