هـيـئـة الـبـيـئـة - أبـوظـبـي
Environment Agency - ABU DHABI

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PREFACE

The rapid growth of the Emirate and associated development has put stress on the environment. Although constant infrastructure change is important to support the growing human population, it is imperative to understand the effects and impacts upon the fragile habitats in this region.

The Abu Dhabi Habitat, Land Use, Land Cover Mapping project is a stunning achievement. Carried out using remote sensing techniques, the project objective was an Emirate wide map created using satellite imagery acquired between 2011 and 2013. This project is the first of its kind in the world in terms of the level of detail and the extent of area covered.

The methods and processes utilised to derive the mapping are detailed here, and statistics are presented that are being used to establish and maintain conservation targets and objectives for the Environment Agency – Abu Dhabi in years to come.

Our intention is to appeal to a wide audience by highlighting key areas and discoveries made during the project, and the key plans afoot to maintain protection and biodiversity. The discovery of extensive coral heads near Al Silaa is a key point regarding the consideration for delineating new protected area boundaries.

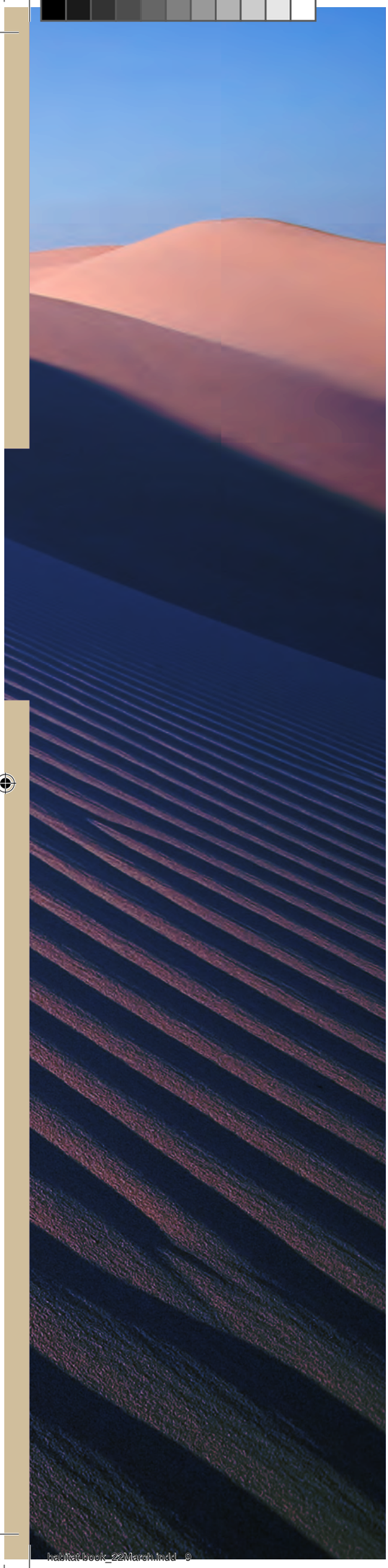
The habitat maps provide a diverse reflection of Abu Dhabi's natural habitats and increasing urban areas, designed to draw the readers' attention and to give context to the targets that must be met under national and international obligations.

I hope that this publication will allow readers to gain a broader understanding of the range and fragility of habitats within Abu Dhabi so that we may all embrace them and ensure their protection for generations to come.

This project is the first of its kind in the world in terms of the level of detail and the extent of area covered.

Razan Khalifa Al Mubarak
Secretary General
Environment Agency-Abu Dhabi

EXECUTIVE SUMMARY



Environment Agency-Abu Dhabi is responsible for managing and conserving the environment and fragile habitats within Abu Dhabi Emirate. Raising awareness and promoting sustainable development are key objectives and this is highlighted within this publication. The Agency has re-introduced the arabian oryx and preserved the dugong population in the midst of growing urban development to support the human population.

An accurate understanding of the current status of the environment and habitats is crucial in achieving the Agency's long term, strategic objectives. The development of the Abu Dhabi Habitat, Land Use, Land Cover Map was commissioned to provide a comprehensive and consistent "baseline" of ecological status across the entire Emirate. The twenty month project has resulted in a map with an unprecedented level of detail and coverage.

The extent of the project is unique; 60,000 km^2 of terrestrial mapping and nearly 30,000 km^2 of marine mapping has been completed at a scale of 1:10,000. Several habitat manuals were used to create a satellite classification system in order to produce a total of 54 different natural and man-made mapping categories at a very fine level of detail, with 41 terrestrial and 13 marine habitat categories. Land Use and Land Cover mapping was also derived from the imagery. Examples of the ground-breaking habitat maps are shown within this book, highlighting areas of critical ecological importance.

In addition to continuous coverage of the entire Abu Dhabi land mass, satellites have been used to map marine areas to water depths of 15 metres. For the very first time at a large scale an accurate understanding now exists of the extent of the Emirate's most fragile habitats. Such information can be combined with other important Environment Agency- Abu Dhabi data sets to assist in conservation and preservation activities of endangered species.

Using change detection techniques it is now possible to update the baseline mapping in rapid time. The loss or gain of critical habitats can be better detected, which in turn can help decision makers to understand how effective environmental policy measures have been. A new method has been introduced and documented enabling repeatability in order to understand long term trends in changes to habitats. Extensive ground truthing was undertaken to validate the accuracy of the final map (terrestrial habitats were validated to 90% accuracy and marine habitats to 83%).

ACKNOWLEDGEMENTS

It is with immense pleasure and satisfaction that we present this book, which details the methods and outcomes of our Habitat, Land use and Land cover Mapping project.

Completed over a period of twenty months, this novel and technologically innovative project led to the creation of a comprehensive habitat, land use and land cover map of the Emirate of Abu Dhabi. Never before has a project of such magnitude - over 90,000 km^2 covering land and sea area, and detail, at a scale of 1:10,000 - been successfully accomplished anywhere, the world over.

Doubtless, work of such stupendous proportions would not have come to fruition without the wholehearted involvement of many, and to acknowledge each individually is next to impossible, that we specifically mention some would not, we hope be construed as slighting the others, who were directly or indirectly involved.

First and foremost, I would like to thank our Secretary General HE Razan Khalifa Al Mubarak, who has not only been the inspiration behind it all, but also ensured that adequate resources were available to successfully complete the project.

Dr Shaikha Al Dhaheri, Executive Director, Terrestrial & Marine Biodiversity Sector (TMBS), extended all support by sparing her team to facilitate an oversight on the scientific validity of the classification scheme adopted in the project and outputs. The TMBS team consisting of Dr. Majid Al Qassimi, Ayesha Al Blooshi, Dr. Salim Javed, Dr. Himansu Das, Ashraf Cibahy, Pritpal Soorae, Maher Al Kabshawi, Rashid Al Zaabi, Ahmed Al Dhaheri, Dr. Shahid Khan and Sabitha Sakkir has been of great support all through the project.

I want to place on record my sincere appreciation to Anil Kumar for conceiving and leading such a technically complex project, Mouza Al Mansouri and Yasser Othman for managing the day to day operations and logistics, ensuring the project stays within the boundaries of cost and time, Ravi Krishna, Hossam El Alkamy and Tariq Al Kharusi for keeping a vigilant eye to ensure the project deliverables meets our stringent quality standards, our data management team consisting of Ravi Krishna and Anuja Vijayan for ensuring that the datasets were validated, stored in EAD's central environmental database (EDB), and is made accessible through the Enviroportal (enviroportal.ead.ae) and iPad app "Beatty", and Amani Issa for providing photographs for this book.

I also want to specially thank Dr. Richard Perry, Edwin Grandcourt and Maher Kabshawi, for their impeccable review and editing of the book's manuscript.

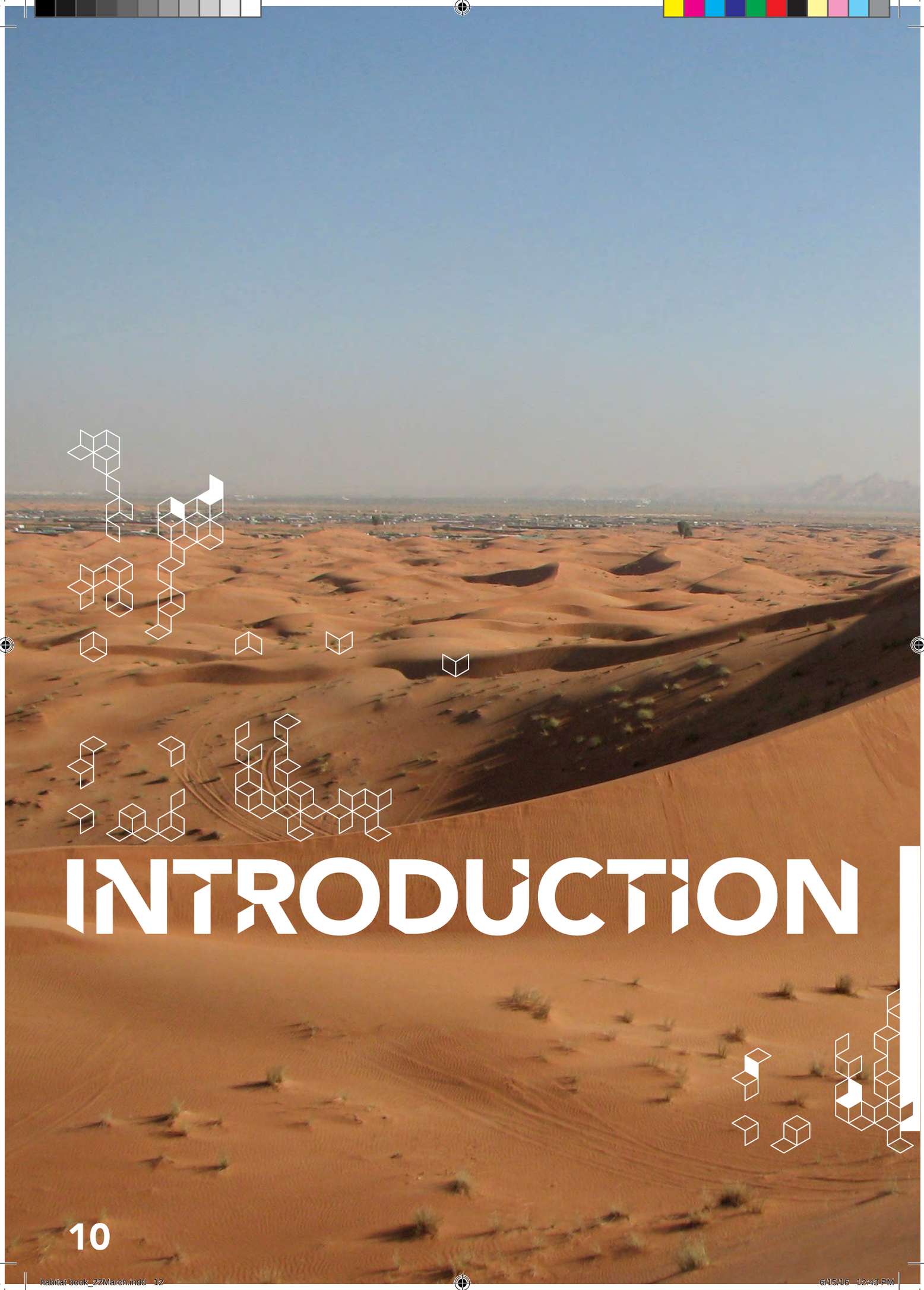
Finally, the work would not have turned into the success it did, had not the team of consultants led by Proteus and including GMV, EOMAP, Digital Globe and Nautica strained every nerve to adhere to the demands of time, quality and finances.

We sincerely hope this offering would prove satisfying to all our stakeholders who have always been our strength.

Ahmed Baharoon
Executive Director
Environment Information, Science
& Outreach Management (EISOM)

GLOSSARY & ACRONYMS

Aichi Biodiversity Targets	A series of targets and strategies created by the Convention of Biological Diversity (CBD) aimed at increasing awareness and management of biodiversity by 2020
Barchanoid	Arc-shaped individual dunes or arc-shaped segments of ridges consisting of loose, very fine to medium sand
CE90	Circular Error with 90% confidence
CMRECS	Coastal Marine Resources and Ecosystem Habitat Classification System
Diapiric	A geological structure formed when material of high plasticity and low density, such as salt, gypsum, or magma, pushes upward into overlying rock
EAD	Environment Agency - Abu Dhabi
Geo-referenced	Data referenced to a known geographic location
GIS	Geographical Information System
IFHC	International Fund for Houbara Conservation
IUCN	International Union for Conservation of Nature
LiDAR	Light Detection And Ranging
MMU	Minimum Mapping Unit
MPA	Marine Protected Area
Multi-spectral	Imagery that can be interrogated in more than one region of the electromagnetic spectrum
Panchromatic	Black and white imagery
Pan-sharpened	Multi-spectral satellite imagery where the resolution has been improved using the panchromatic band for finer analysis
RapidEye	Satellite used to image marine areas and derive marine habitat mapping
Resolution	Size of an image pixel on the ground
SDB	Satellite Derived Bathymetry
Swath	Image width
Thematic	A dataset or map relating to a particular theme
UNESCO	United Nations Educational, Scientific and Cultural Organization
Vegetation Cover Fraction	A percentage or fraction of vegetation covering a known area
Wentworth Scale	A scale for specifying the sizes (diameters) of sedimentary particles
WorldView-2	Satellite used to image terrestrial areas and derive terrestrial habitat mapping



INTRODUCTION

The need for up-to-date habitat mapping information is extremely important in countries such as the UAE where the human population is increasing and there is a growing demand for improved infrastructure. Understanding the locations and types of habitat is critical to estimating the impact development will have upon the surrounding wildlife.

In early 2013, the Environment Agency-Abu Dhabi commissioned the Abu Dhabi Habitat, Land Use, Land Cover Map for the entire Abu Dhabi Emirate. State of the art satellite processing technologies have been deployed to provide terrestrial and marine mapping at a scale of 1:10,000 covering a vast land area of 60,000 km^2, and a marine area of 30,000 km^2. No other survey technique would have allowed for the coverage, accuracy, and consistency of the mapping on such a grand scale in a short time frame and with limited resources.

The project output serves as a baseline to assess the current state of fragile habitats in Abu Dhabi Emirate, and to build a picture of change over time with the introduction of repeat mapping.

MAPPING HABITATS

The mapping solution deployed here has combined multiple disciplines, and demonstrated a unique interpretation of traditional land use/land cover mapping methods. Two different methods were utilised; a marine habitat mapping work flow and a terrestrial habitat mapping work flow. Outputs from both processing work flows have been combined to deliver a seamless transition across all areas of the Emirate. The final maps have a proven level of combined thematic accuracy that exceeds 87%.

TERRESTRIAL MAPPING WORK FLOW

Terrestrial habitat mapping begins with an image processing and segmentation work flow where distinct spectral characteristics are identified within the WorldView-2 images which are then grouped into homogeneous pixel areas. Segments partition high resolution imagery into meaningful objects by assessing their spectral and spatial characteristics. Segmentation of the Abu Dhabi imagery has been significantly improved with the high availability of ground truth data. The terrestrial image interpretation was continuously updated during the project with regular field survey missions and frequent communication between the satellite processing team and the field survey teams.

Within the terrestrial habitat work flow Minimum Mapping Units (MMUs) have been implemented. The MMU is the minimum size or dimensions for a feature to be mapped for a given map scale (in the case of this project, 1:10,000 scale).

For the final terrestrial map to be meaningful, many cartographic generalisation rules have been implemented. For example, for a habitat containing trees to be correctly classified there must be a minimum number of trees per hectare, and a minimum distance between trees. Many of the cartographic generalisation rules can be automated within GIS software, but there is also an element of human quality control to check the final output.

MARINE MAPPING WORK FLOW

Until recently, seafloor mapping was exclusively conducted by sonar or LiDAR. Recent breakthroughs in image acquisition and processing technology have made remote sensing satellites viable for marine mapping in depths down to 15 metres in the Arabian Gulf. The processes deployed here have produced output of both bathymetry (sea floor depths) and seabed classification (habitats).

The principle of Satellite Derived Bathymetry (SDB) involves the absorption and refraction of the satellite's multi-spectral bands through the atmosphere and water column. Correction factors need to be applied to counteract the absorption and refractions which occur, before converting this into a tidally corrected depth. A depth value every 5 metres in the horizontal plane has been provided as a deliverable of the project. This derived data is also being used as an important input into the satellite derived habitat mapping and sea floor classification work flow.

Within the Abu Dhabi project, marine ecological classifications have been based on supervised classification methods. The high quality of available ground truth data has made this preferable to unsupervised methods.

A unique processing technique is used that removes the effects of sun reflectance and water column interference to output the reflectance of the sea bottom. The sea bottom reflectance is then used as an input for the classification.

As with the terrestrial processes, the classification process uses image segmentation to derive habitats. Segmentation in Abu Dhabi waters was significantly improved with the availability of ground truth data as a "training" data set to identify common spectral behaviour in the image.

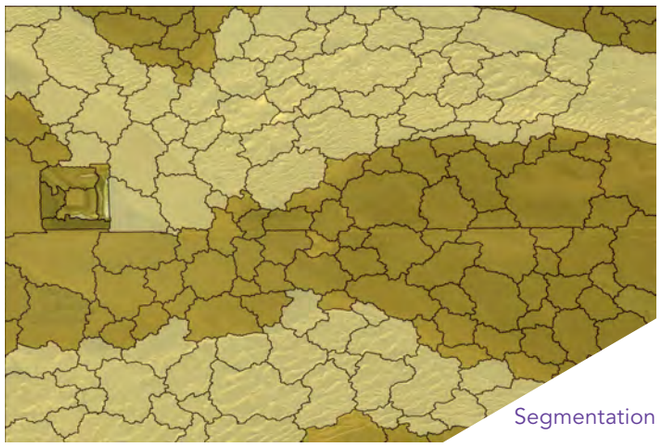
A PROVEN LEVEL OF ACCURACY

The accuracy of the map is proven using the traditional remote sensing method of a confusions matrix. This compares the map with an independent source to verify correctness. In this project, field "ground truth" has been compared to the map output in 385 terrestrial locations, and 58 marine locations. To remove bias from such a comparison, the points were placed randomly throughout the Emirate.

MAPPING HABITATS

Satellite image

Texture /Context



Segmentation

Classification

Multispectral bands of WorldView-2 image

COASTAL
Coastal applications, water penetration, deep water masks, materials differentiation, shadow-tree-water differentiation

BLUE
Coastal applications, water body penetration, discrimination of soil/ vegetation, forest types, reef over features

GREEN
Crop types, sea grass and reefs bathymetry

YELLOW
Leaf coloration, plant stress, algal blooms, crop identification, shadow vs water, separability of iron formations, 'true colour'

RED
Chlorophyll absorption, vegetation analysis, plant species and stress

RED EDGE
Vegetation health, stress type and age, sea grass and reefs, land/no land, impervious from vegetation, turbidity, camouflage

NIR 1
Biomass surveys, plant stress, delineation of water bodies, soil moisture discrimination

NIR 2
Biomass surveys, plant stress, urban mapping, materials differentiation

Texture /Context

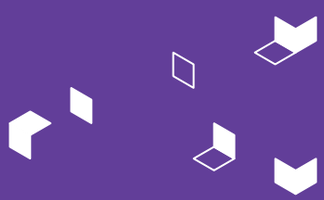
In Situ Data

COMBINING SATELLITE IMAGERY WITH LOCAL KNOWLEDGE

DigitalGlobe WorldView-2 multi-spectral satellite imagery has been utilised for the land and near-coastal zones in the habitat delineation project.

WorldView-2, launched in October 2009, has an average revisit time of 1.1 days and is capable of collecting up to 1 million square kilometres of 8-band imagery per day, providing a rapid and reliable collection capacity. WorldView-2 represents a departure from the multi-spectral capabilities of other commercial imaging satellites. In addition to its 46cm panchromatic band, the satellite captures eight multispectral bands at 1.85 m resolution, twice the number of multispectral bands of its predecessor, QuickBird. The DigitalGlobe WorldView-2 satellite boasts the following features:

- Very high resolution
- 4 standard colour bands; blue, green, red, near Infrared 1
- 4 additional colour bands; coastal, yellow, red edge, near Infrared 2
- Industry leading geo-location accuracy
- High capacity over a broad range of collection types
- Bi-directional scanning
- Frequent revisits at high resolution



The wavelengths of the additional bands – Coastal Blue, Red-Edge, Visible Yellow and Near Infrared – were carefully selected to maximize feature classification both on land and in the coastal zone.

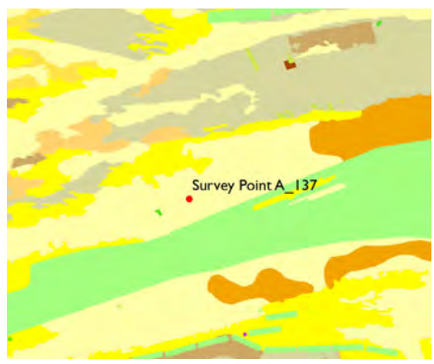
In areas further offshore, Blackbridge RapidEye satellite imagery has been utilised. This satellite captures five spectral bands at 5 metres resolution. A lower resolution product was deemed suitable for the homogeneous habitat coverage that is generally experienced in the slightly deeper Abu Dhabi waters.

Satellite	WorldView-2	RapidEye
Number of satellites	1	5
Horizontal Accuracy CE90	5 m	14 m
Multiple Resolution	2 m	5 m
Number of Spectral Bands	8	5
Image Swath	16.4 km	77 km

FIELD SURVEY VERIFICATION DATA

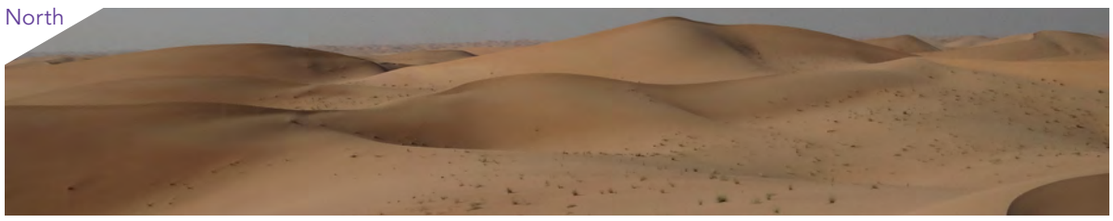
The accuracy of satellite derived mapping can be significantly improved with the introduction of field verification data. For the purpose of habitat mapping, field data not only improves positional accuracies, but also thematic accuracies.

The habitat delineation project method is designed around close collaboration between local ecological experts in the field and satellite processing teams. The ecologists made regular field missions to verify habitats at specific locations. A total of 385 points were observed to validate the terrestrial mapping with an accuracy of 90.4%, while 58 points were observed in marine environments to ensure a mapping accuracy of 83%. The outcome is a large database of geo-referenced photographs and field notes used to verify the map content. This information was used to train the processing algorithms to correctly identify spectral signals and associate them to specific habitats.

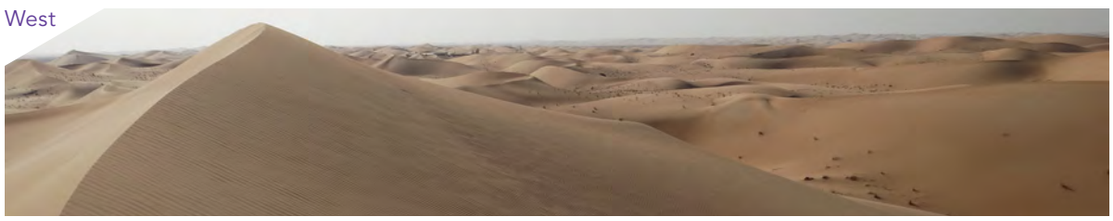


An example can be seen in the following images, where a terrestrial habitat location has been visited and georeferenced photographs taken facing north, south, east and west have been captured to help with map verification.

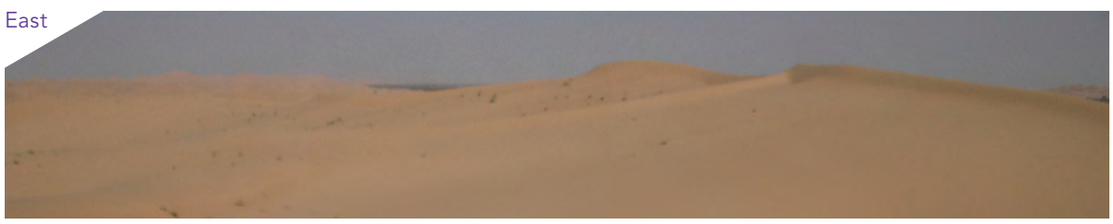
North



West



East



South

HABITAT CLASSIFICATION

The terrestrial map categories were primarily based on the *Interpretation Manual of the Major Terrestrial Natural and Semi-Natural Habitat Types of Abu Dhabi Emirate* produced by Brown and Böer. This interpretation manual was originally designed for use by biodiversity experts for field based classification. The manual therefore had to be adapted and refined to suit the constraints of satellite classification and interpretation. 41 terrestrial and coastal map categories were used, representing a very high level of thematic detail. For example, it has been possible not only to distinguish Sand Sheets and Dunes from other surface types, but also to provide four sub-categories of Sand Sheets and Dunes depicting varying types of vegetative cover.

It has been possible to derive 13 different habitats in Abu Dhabi marine waters. These are based on the *Coastal Marine Resources and Ecosystem Habitat Classification System (CMRECS) Manual.* The manual, produced for EAD in 2009, also had to be adapted for satellite application.

The major advantage of using CMRECS as a base for defining habitat categories is that the categories are biologically driven, not satellite derived. An example of this is the "Substrate Modifier" within the CMRECS publication. Using the Wentworth scale, substrate that is "Gravel" size or smaller (less than 4mm) is classified in this project as "Unconsolidated Bottom". Whereas substrate that is "Pebble" size or larger (greater than 4mm) is classified as "Hardbottom".

It has been possible to derive 54 different map categories across the Abu Dhabi Emirate. These represent a mixture of detailed, natural and seminatural habitats as well as human land use categories. Close coordination between Environment Agency-Abu Dhabi, the satellite processing team and local ecological consultants has resulted in a comprehensive terrestrial habitat manual that provides detailed descriptions of the characteristics of each habitat.

The habitat manual associated with this map will not only provide a thorough user guide for the outputs of the project, but also ensure repeatability and consistency in future iterations of satellite processing. The examples below show how the habitats and subhabitats are interlinked.

Habitat Type	Habitat Sub-Type
1000 Intertidal Habitats	1010 - Mudflats and sand exposed at low tide 1020 - Sheltered tidal flats with cyanobacterial mats 1030 - Saltmarsh 1040 - Mangroves 1050 - Storm beach ridges 1060 - Sandy beaches 1070 - Beach rock and gravelly beaches
8000 Oases, Farmland and Forestry	8100 - Date plantations 8200 - Farmland 8300 - Livestock areas 8400 - Forestry plantations

MAP LEGENDS

MAP LEGEND

Note: the number refers to the habitat code, text refers to habitat name

HABITAT

- 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/Artificial Reef
- 15200 - Marine Structure
- 16100 - Dredged Seabed
- 16200 - Dredged Area Wall
- 17000 - Deep Sub-Tidal Seabed
- 1010 - Mudflats And Sand Exposed At Low Tide
- 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
- 2012 - Coastal Plains On Well-Drained Rocky or Gravelly Terrain
- 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 Shabkha
- 6100 - Mountain Slopes, Screes 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

Maps created from satellite imagery classification and supporting field data.

Sources include:
- WorldView-2 satellite multi-spectral scenes from 2011, 2012 and 2013
- RapidEye satellite scenes from 2012 and 2013
- Road network provided by Abu Dhabi SDI community
- Place names provided by Abu Dhabi SDI community

Note: These maps are not an authority on international or inter-emirate boundaries

Note: These maps should be used in conjunction with the Habitat, Land Use and Land Cover Delineation Project 2014 Classification Manual

LAND USE

- 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

BASE MAP LEGEND

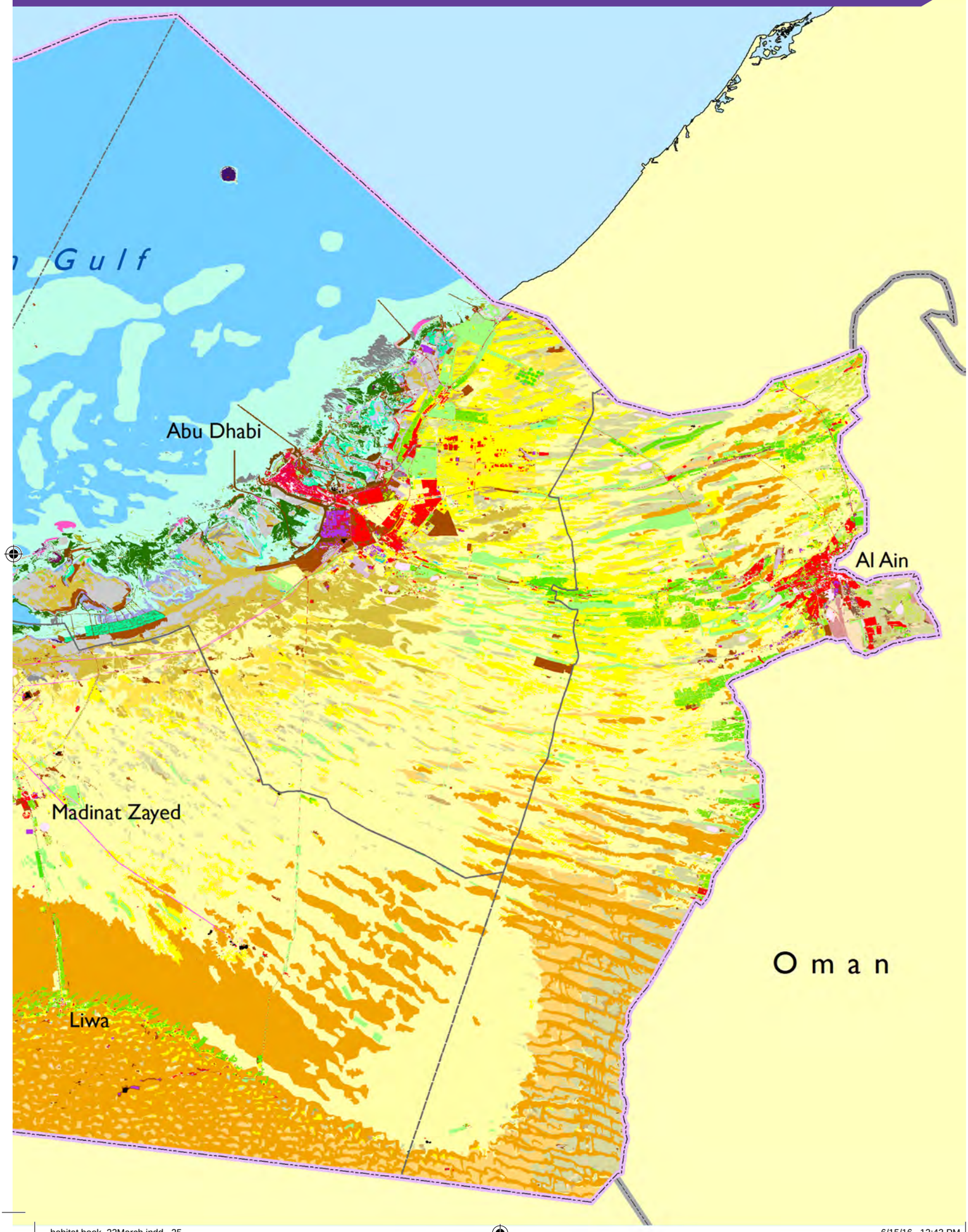
- International Boundary
- Emirate Boundary
- Municipality Boundary
- Protected Area or Reserve

Projection	Transverse Mercator
Ellipsoid	World Geodetic System 84
Horizontal Datum	World Geodetic System 84
Longitude Origin	Meridian 54° E of Greenwich
Latitude Origin	Equator
False Coordinates of Origin	500,000m E 0m N
Scale Factor at Central Meridian	0.99995

Note: This table of contents provides the map subjects and mapping scales

ABU DHABI EMIRATE

MARINE AND TERRESTRIAL HABITAT MAP



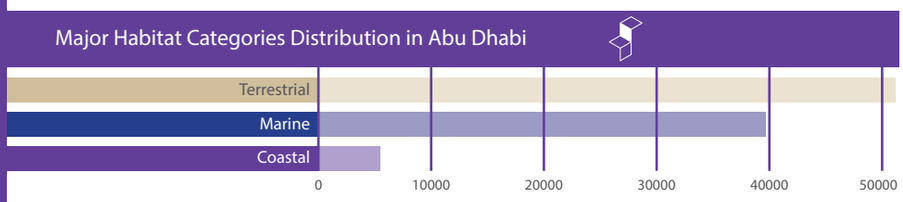
FACTS & FIGURES

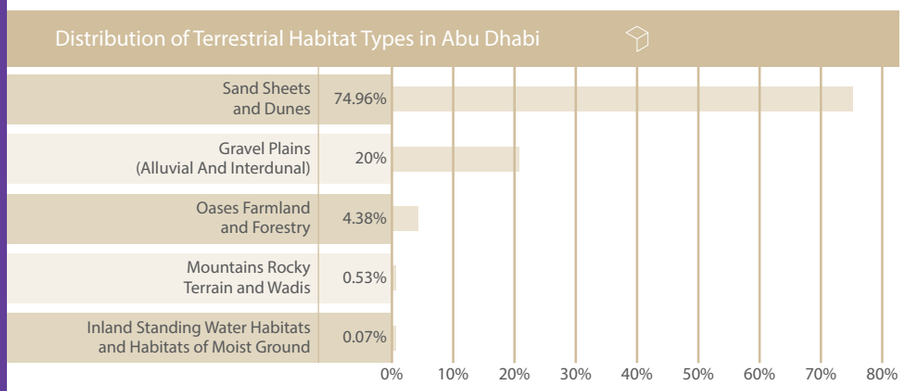
The Ecological Classification and Landuse Mapping from Satellite Imagery project has provided some valuable statistics to compare against targets that have been set for protected areas.

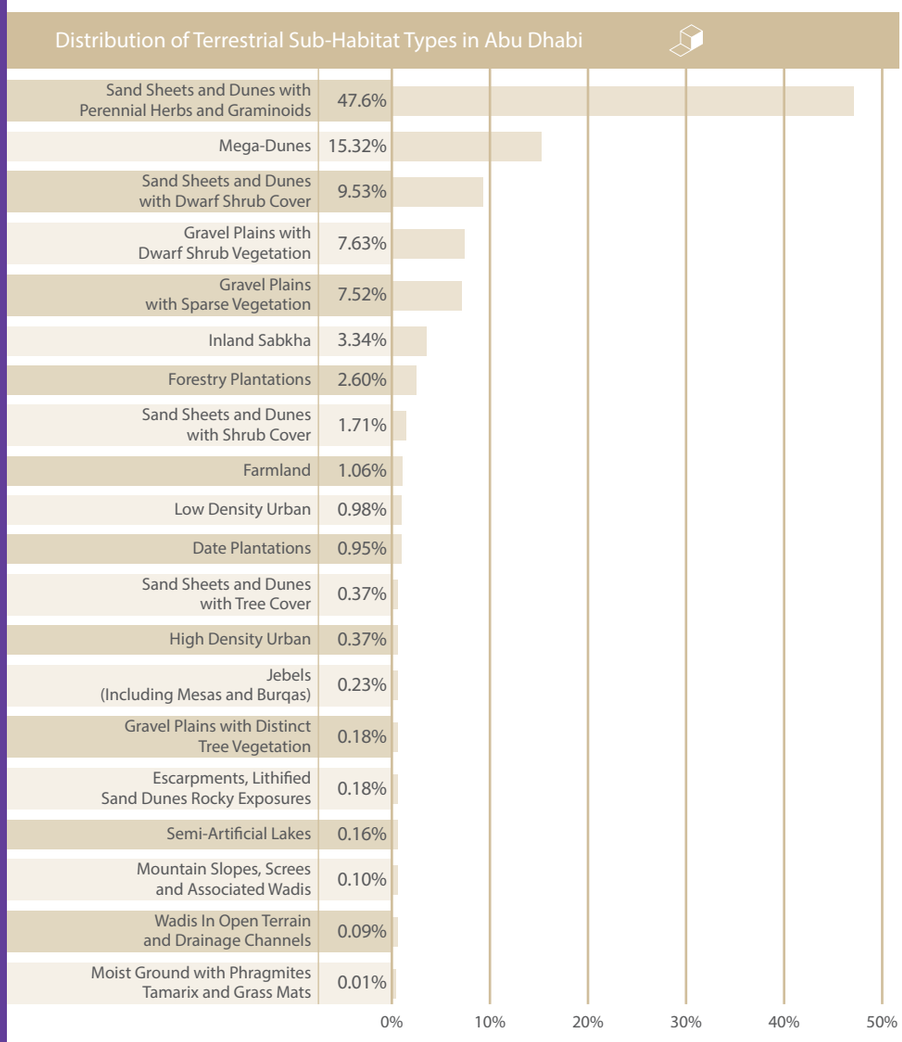
Just over 60,000km² of terrestrial habitats have been mapped using a total of 41 different categories with 16% of these habitats found in protected areas.
It has been possible to map 14,000km² of the 13 marine habitats, where 25% of Abu Dhabi's waters are protected.

The delineation of habitats from the mapping project has been invaluable in portraying the type and percentage of habitats found within protected areas, as indicated by the following graphs that indicate the habitat types, and these are then broken down into habitat sub-types.

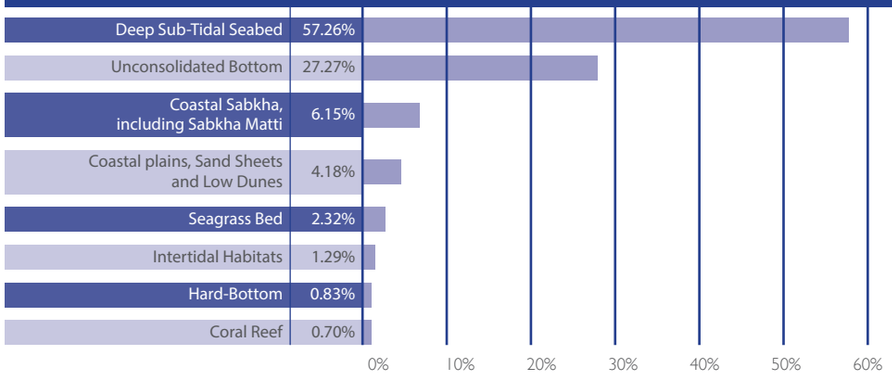
The statistics shown here indicate the percentage of habitats found within protected areas. Analysing the dataset in this way allows EAD and the UAE government to observe and set targets for habitats within protected areas. Trends can be identified and monitored through the use of repeat mapping and this information can be fed into MARXAN analysis software in order to re-define or establish new protected areas.



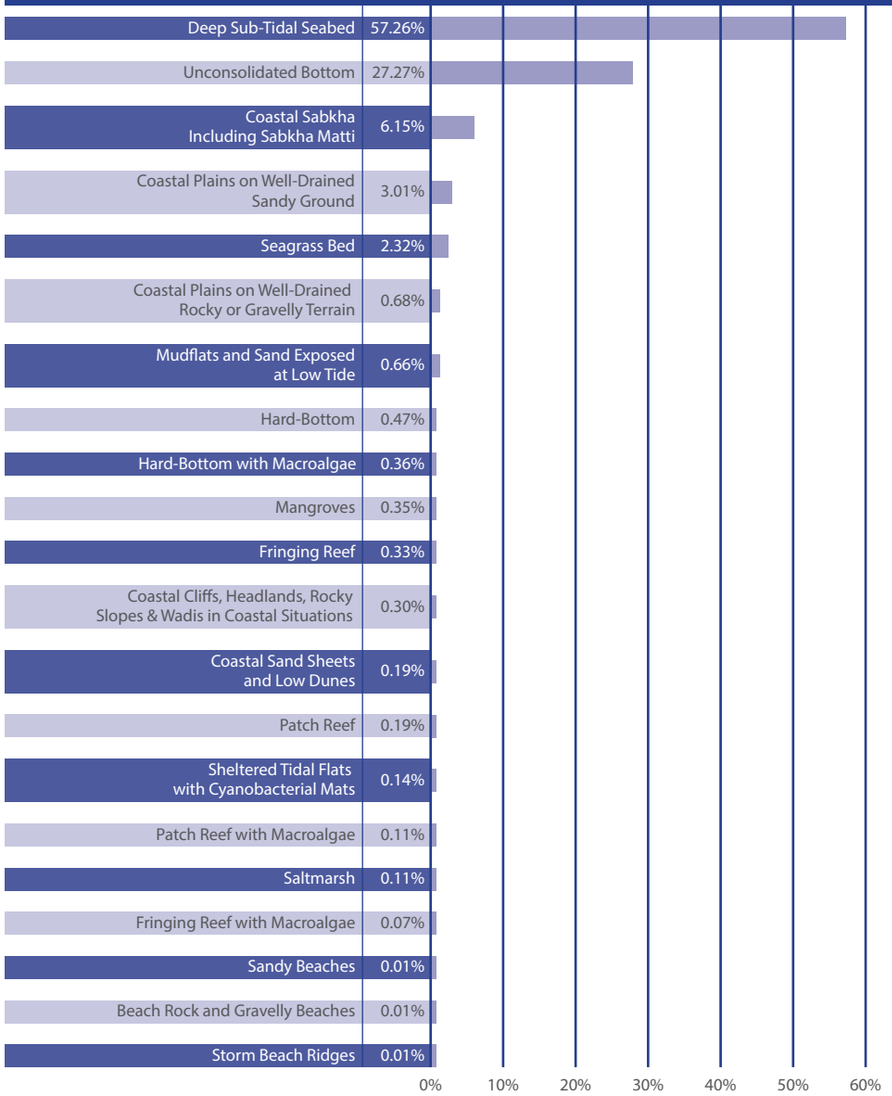


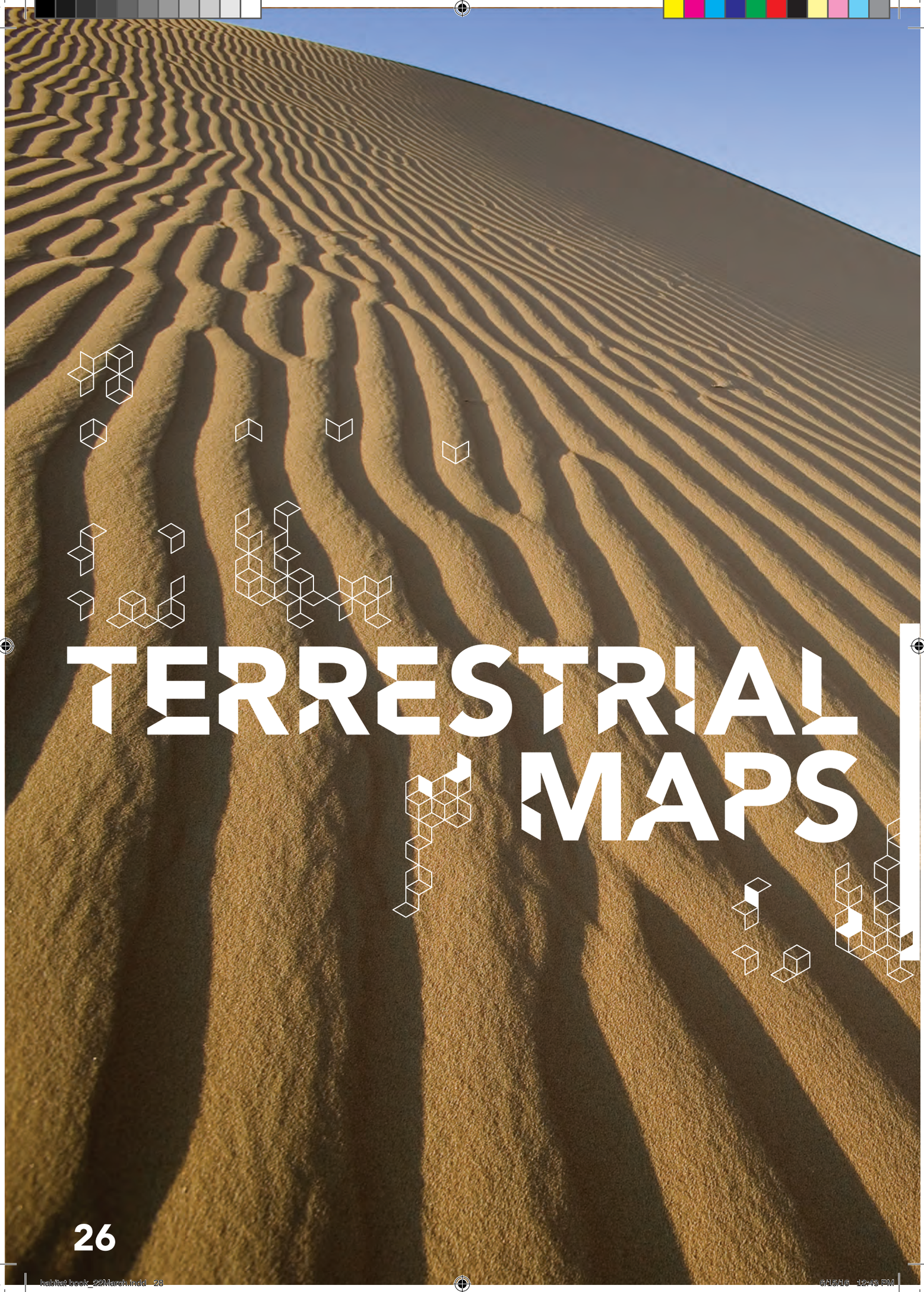


Marine Coastal Habitat Classes Distribution in Abu Dhabi



Marine Coastal Sub-Habitat Classes Distribution in Abu Dhabi





TERRESTRIAL MAPS

Continuing economic growth of Abu Dhabi Emirate is proceeding at a rapid pace, and it is important to ensure the protection of critical terrestrial habitats. They are under threat from unsustainable development such as; overgrazing, encroachment of urban areas and construction of linear features such as roads, railways, pipelines, powerlines, walls and fences.

The diversity of Abu Dhabi's terrestrial habitats is explored within the following maps. From megadunes to forestry plantations, the preservation of these habitats is key to supporting the Emirate's wildlife.

The terrestrial habitat maps following this page are represented by 41 different categories, with the major terrestrial habitat being sand sheets and dunes that include a variety of seasonal vegetation. The Emirate also includes the north-eastern corner of the world's largest sand desert, the Rub al Khali or "Empty Quarter."

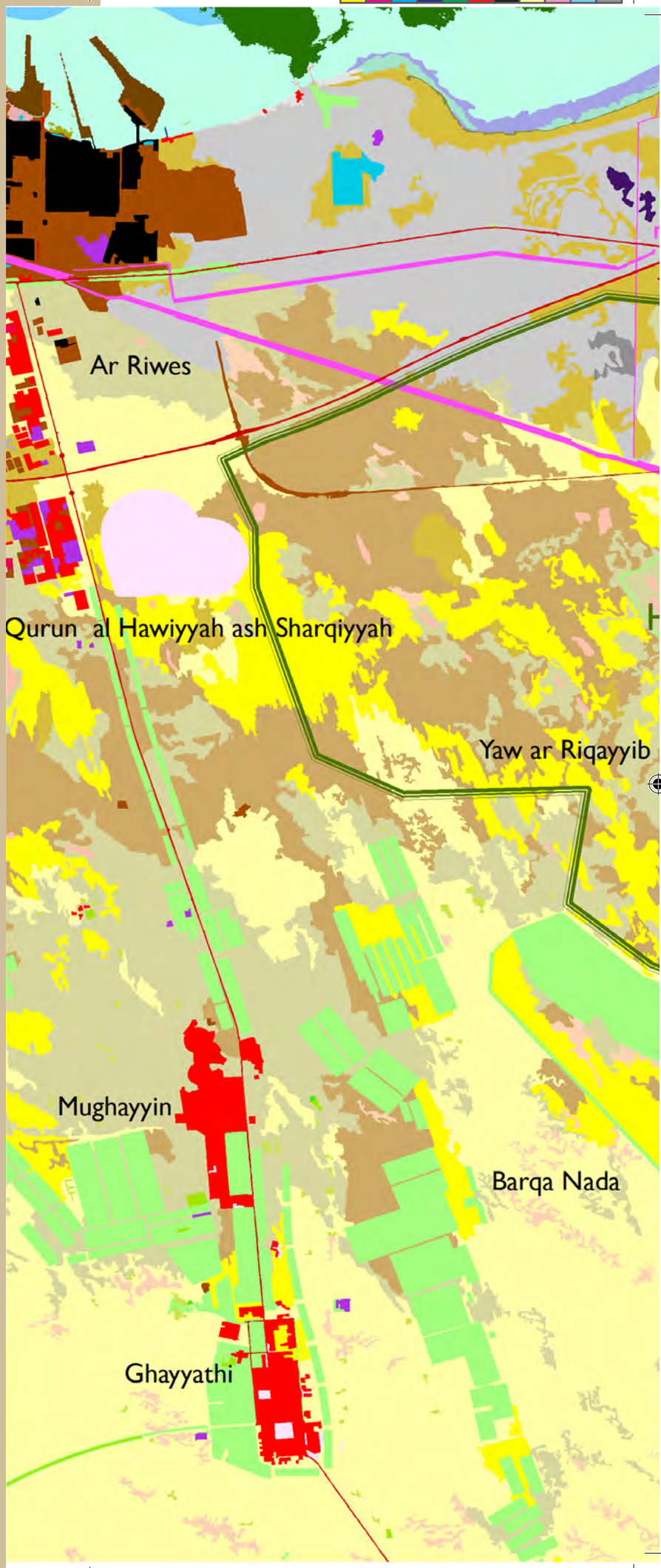
Forestry plantations are located amongst the dunes as part of a concerted effort to improve the biodiversity of the region. This is coupled with increased farming, particularly in areas such as Liwa and Al Ain, to allow the increasing population to survive and reduce the need for imported foods.

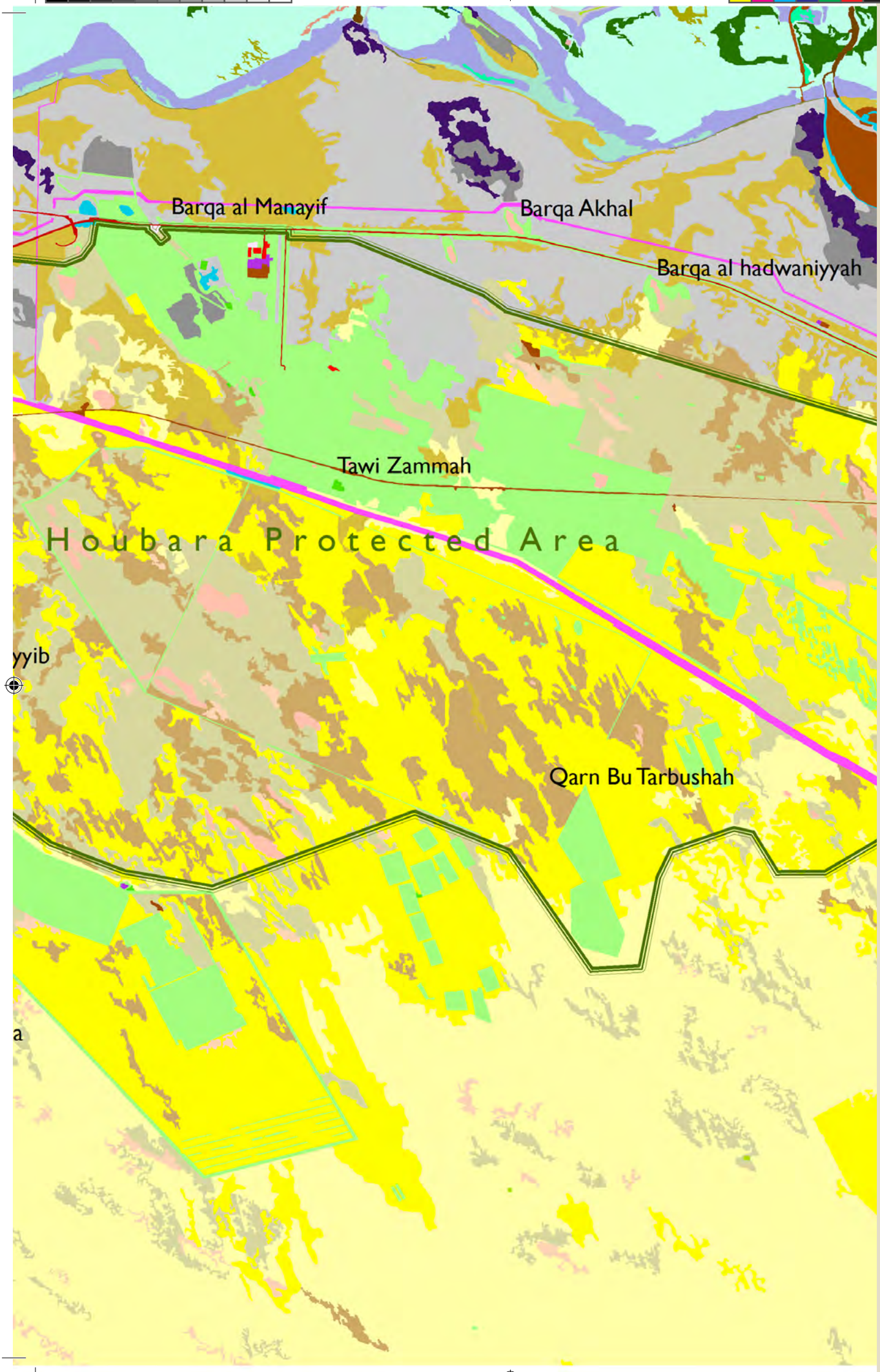
HOUBARA PROTECTED AREA

Baynunah has been selected as the site for a large Houbara Protected Area due to the lack of human disturbance, relatively light grazing and range of habitats suitable for Houbara.

Many Houbara Bustards spend the winter in UAE, flying vast distances on migratory routes from Iran, Afghanistan, Kazakhstan and even China and Mongolia. Their favoured habitat is in arid sandy and stony semi-desert with sparse vegetation, such as the sand sheetsand gravel plains of Baynunah.

More than 6,000 Houbara Bustards were released into the wild in UAE in 2013 from a breeding programme in Abu Dhabi. The global population of the species was in sharp decline due to their use as prey in falconry. Houbara are protected by legislation in UAE and other range states. A project for rehabilitation of Houbara Bustards is ongoing under the auspices of the International Fund for Houbara Conservation (IFHC).



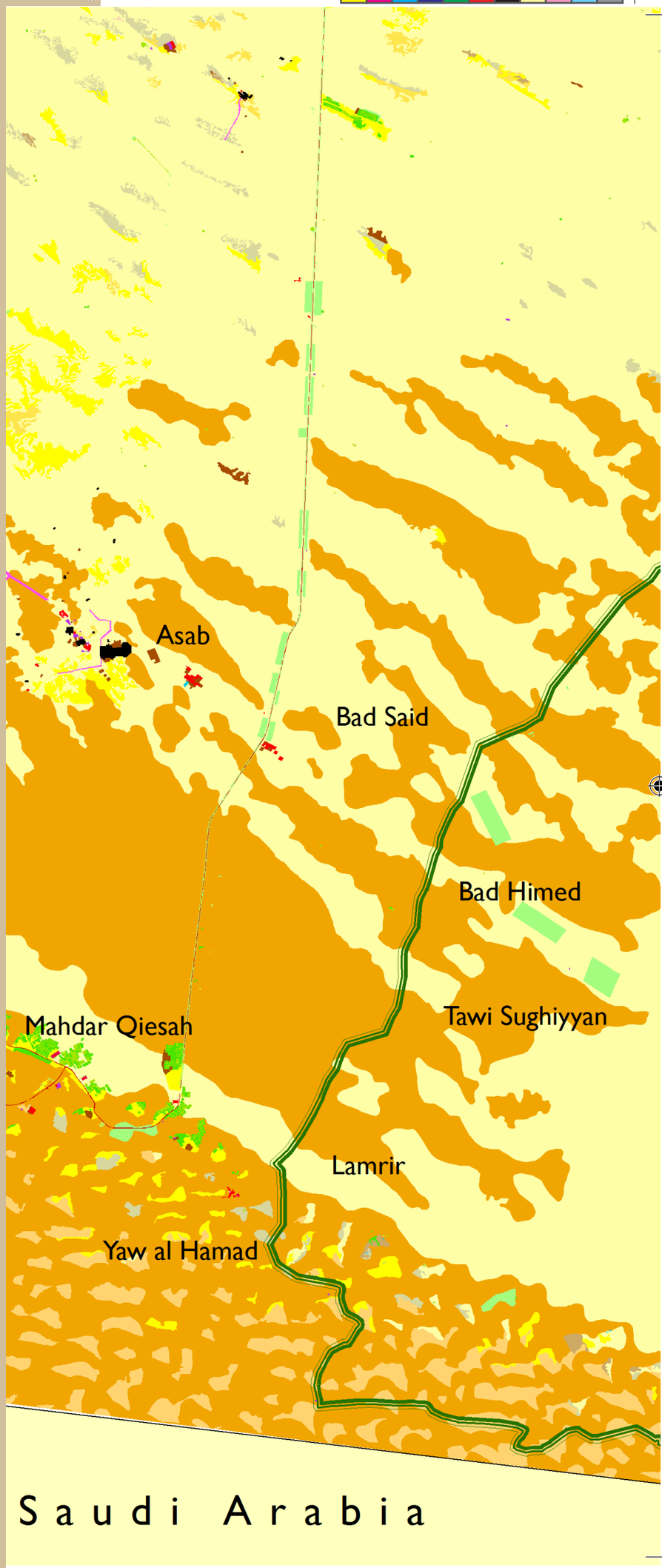

Barqa al Manayif
Barqa Akhal
Barqa al hadwaniyyah
Tawi Zammah
Houbara Protected Area
yyib
Qarn Bu Tarbushah
a

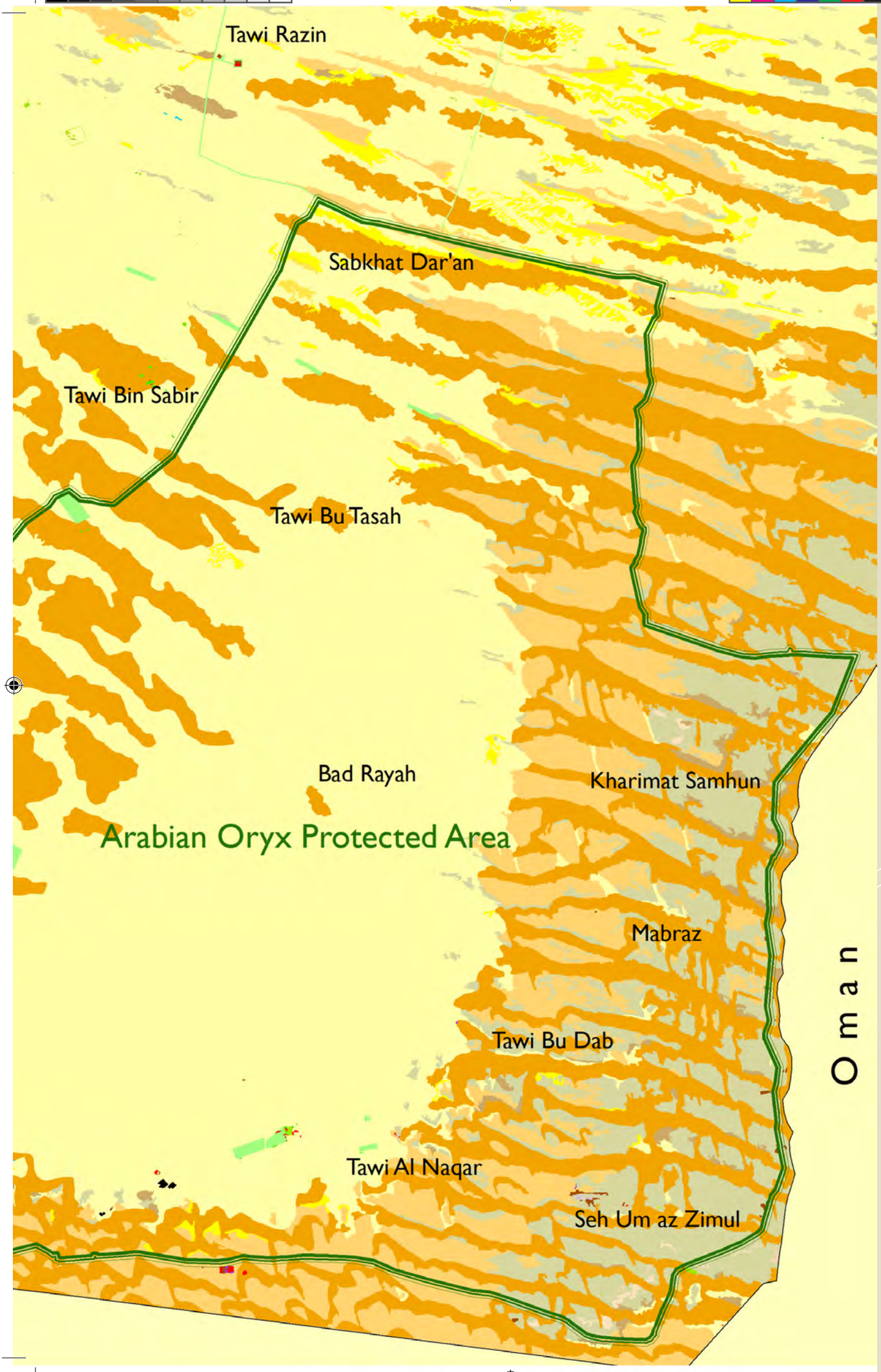
THE EMPTY QUARTER

The "Empty Quarter" or Rub' al Khali is a vast expanse of desert larger than France, Belgium and The Netherlands combined, and this extends into Saudi Arabia, Oman, Yemen and the UAE. Oil reserves were formed millions of years ago when the area was a tropical rainforest. The climate changed and huge quantities of wind-blown sand were deposited on top of the former land surface. Oil and gas from deep deposits are now pumped to terminals on the Gulf coast by a network of pipelines.

Although biodiversity is minimal in the Empty Quarter, the area does support indigenous wildlife including gazelles, oryx, sand cats, gerbils and spiny-tailed lizards. Arabian oryx was hunted to extinction in the wild but, before that, some were taken into captivity in order to preserve the species. Captive-breeding began in the 1960s in Al Ain, followed by successful breeding programmes in other places. The species is now protected and managed through the Coordinating Committee for the Conservation of the Arabian Oryx, initiated in 1999.

In 2007 Arabian Oryx were released into an area near Um Az Zimul in the Empty Quarter, and as of 2009 about 100 animals have been released.



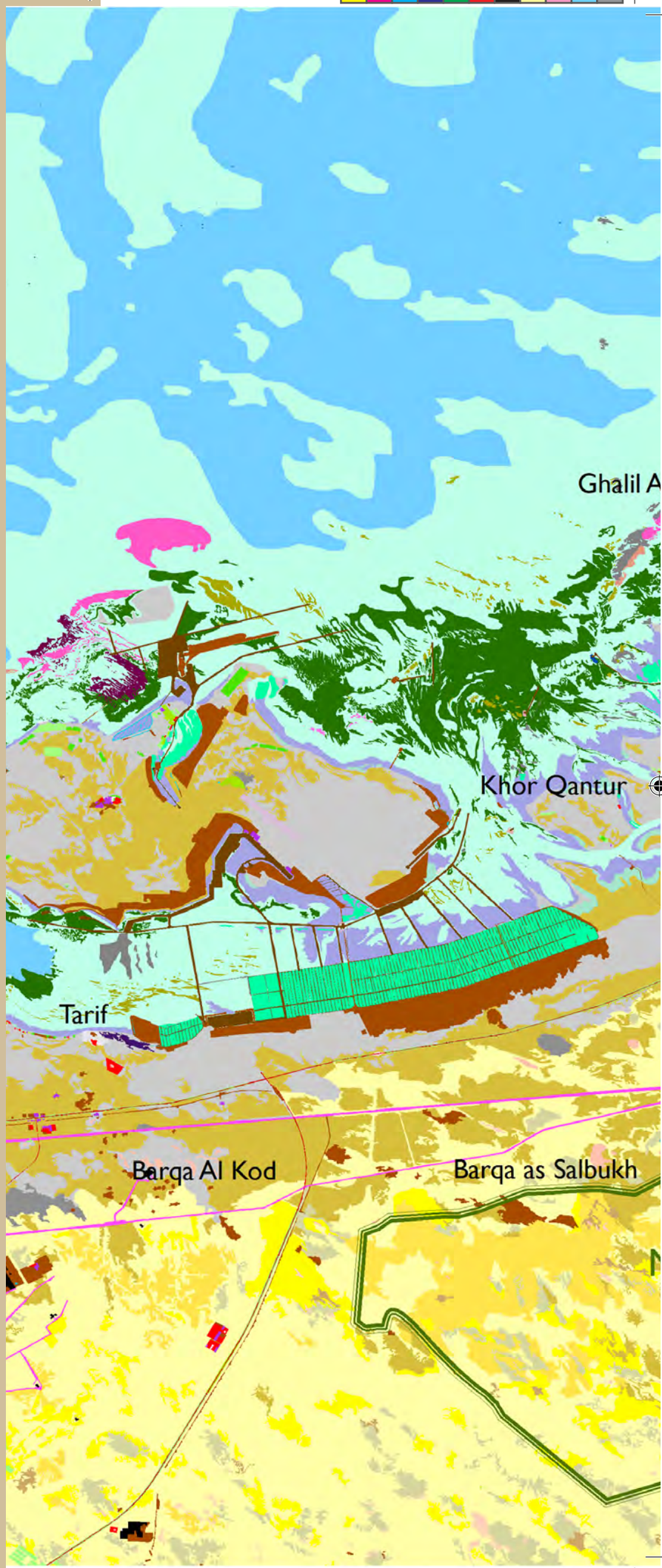

Tawi Razin
Sabkhat Dar'an
Tawi Bin Sabir
Tawi Bu Tasah
Bad Rayah
Kharimat Samhun
Arabian Oryx Protected Area
Mabraz
Tawi Bu Dab
Tawi Al Naqar
Seh Um az Zimul
Oman

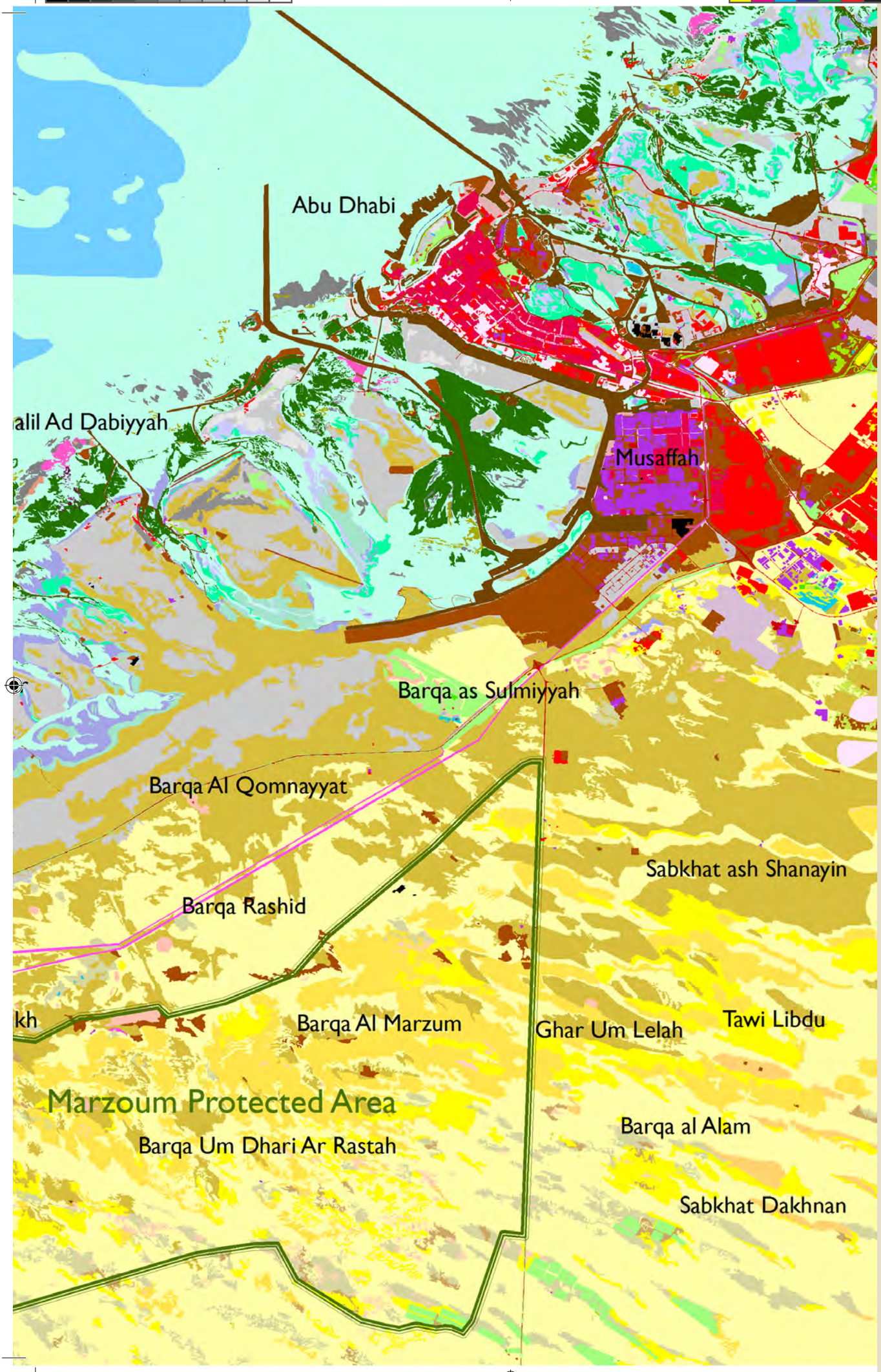
DEW FOREST

The Dew Forest is the name given to an area dominated by 2 to 3 metre high saxaul, *Haloxylon persicum*, trees (or Ghada) located to the south-west of Abu Dhabi city. This is on the extreme southern fringe of the global range of the species.

The area is aptly named due to the trees constantly dripping condensation, allowing the trees to water themselves before the dew evaporates. The smooth pendulous and virtually leafless stems are well adapted to allowing water to run down and drip onto the ground, and thus into the root zone. The area is unique given that it is the only native forest, covering just 1% of the total area of the UAE. The distribution of the trees is determined by the interplay of coastal fog and salinity of the ground. To the north of the Dew Forest, the terrain is too saline, and to the south there is insufficient coastal fog to meet the water requirements of the trees.

The Dew Forest supports a multitude of wildlife, including hares, gerbils, red foxes, eagle-owls, diurnal raptors and many other species of bird.




Abu Dhabi
alil Ad Dabiyyah
Musaffah
Barqa as Sulmiyyah
Barqa Al Qomnayyat
Sabkhat ash Shanayin
Barqa Rashid
kh
Barqa Al Marzum
Ghar Um Lelah
Tawi Libdu
Marzoum Protected Area
Barqa al Alam
Barqa Um Dhari Ar Rastah
Sabkhat Dakhnan

LIWA CRESCENT

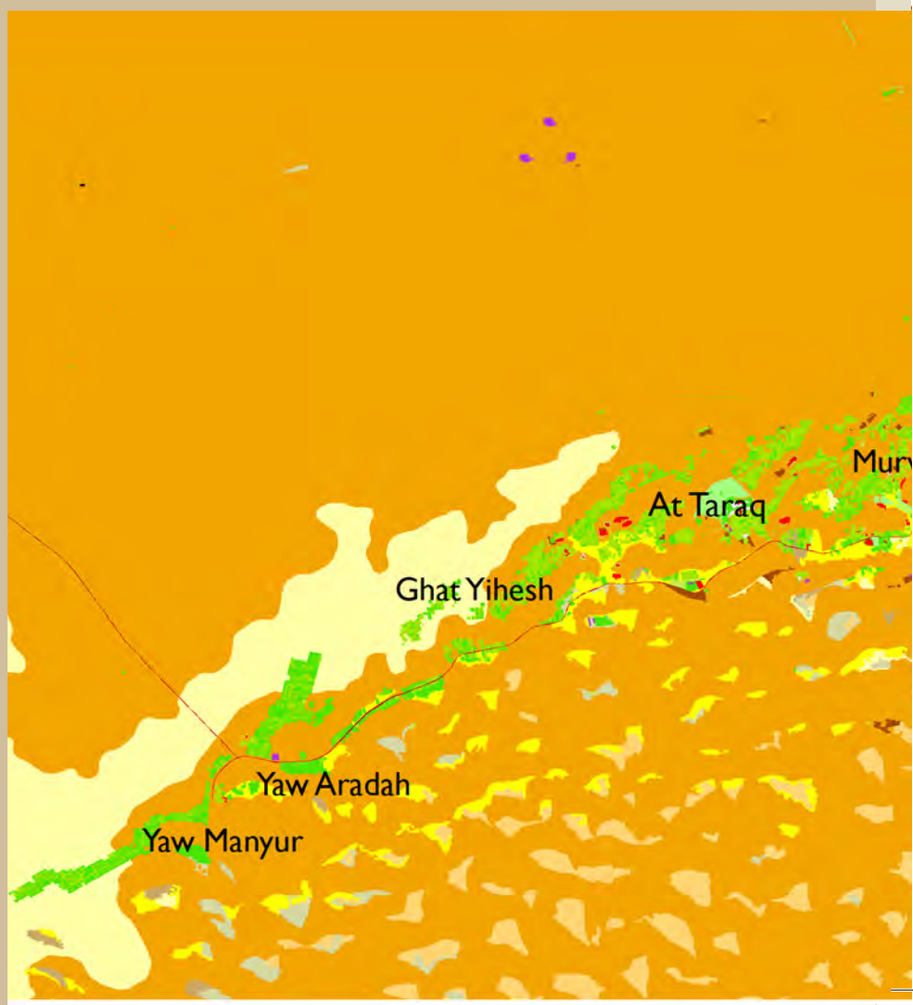
The line of former natural springs that form an arc, almost 100 kilometres long, in the southern part of the Western Region are known as the Liwa Crescent.

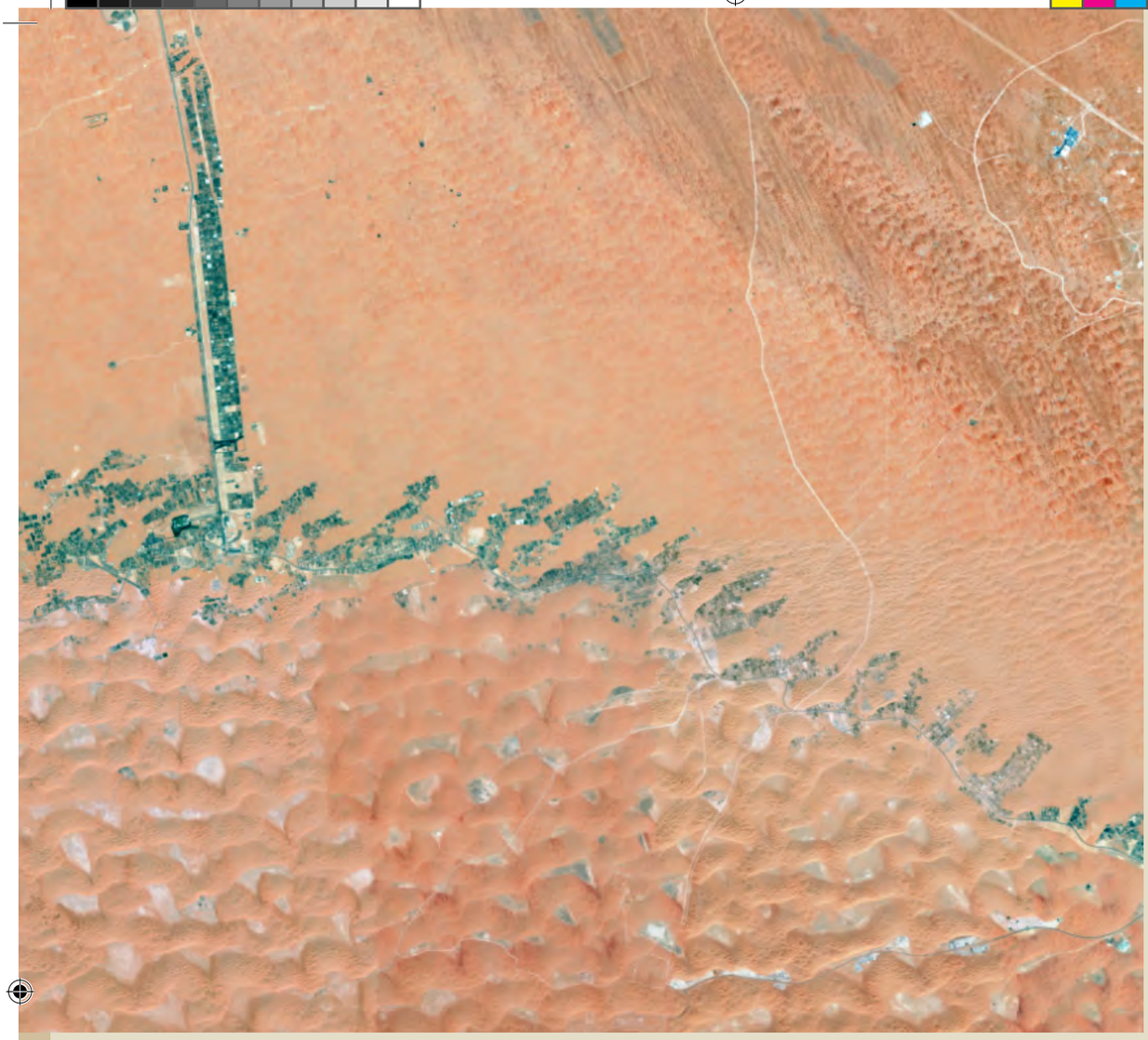
Centuries ago, the groundwater near the surface at the foot of high dunes permitted the creation of permanent human settlements and the cultivation of dates, fruit, vegetables and fodder for livestock. The string of old forts, most of them now carefully restored, bear witness to the need to defend this area.

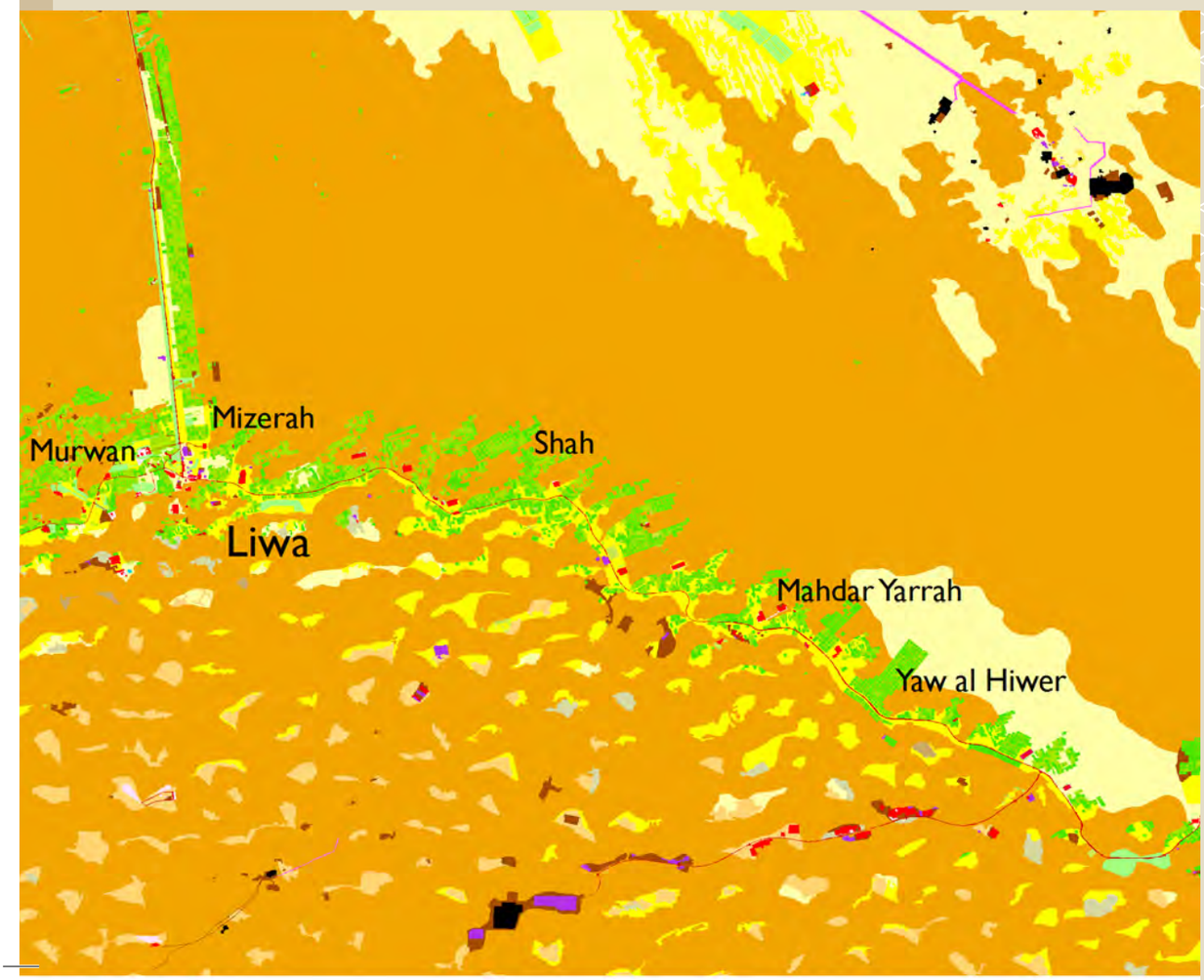
Development of the water supply and irrigation system has facilitated a massive expansion of agriculture and date palm cultivation. Today, the crescent contains around 15 towns that are served by a good road system, with many schools, mosques and other facilities for the large resident population. Visitors can use a Heritage Trail and even visit a fish farm.

The Liwa Crescent lines the northern edge of the Rub al Khali, or "Empty Quarter" which stretches deep into Saudi Arabia. "Liwa" is the general term used for the large area of barchanoid dunes within Abu Dhabi Emirate that rise to 150 metres in height, some of the highest dunes in the world, and contain sands that were first deposited some 141,000 years ago. Within the dunes there are many large inland sabkhas, representing the level of a former lake. In these areas the water table is very close to the surface, and there can be a lot of standing water after rains. The underlying salt is drawn up by the evaporating water, creating a halite crust which can vary in colour from white to grey to dark brown with a red-orange tinge. The prevailing pattern of the landscape is of steep scarp slopes on the northern side of the sabkhas, and more gentle slopes on the southern side.

The satellite image clearly shows the stark contrast between the irrigated landscape of the Liwa Crescent and the surrounding desert, with an abundance of inland sabkhas to the south.






Murwan
Mizerah
Shah
Liwa
Mahdar Yarrah
Yaw al Hiwer

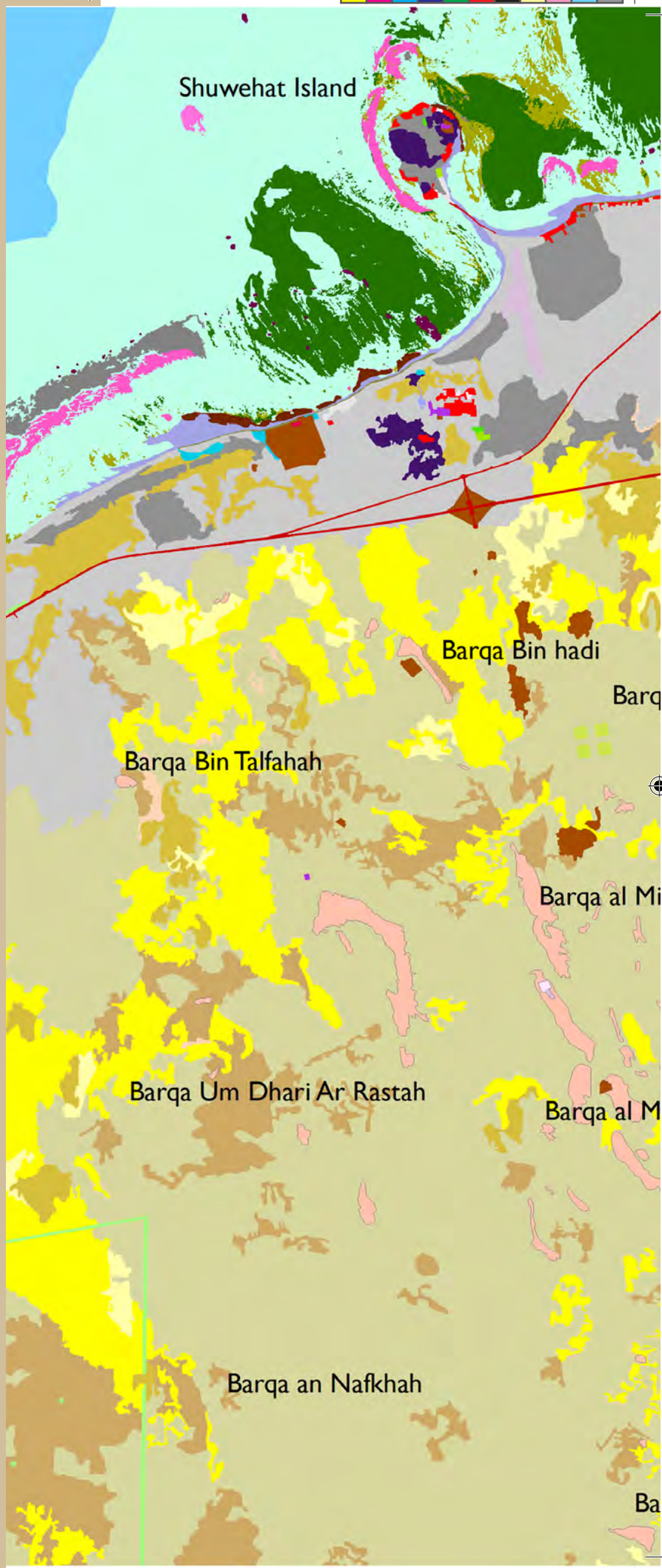
BARQA

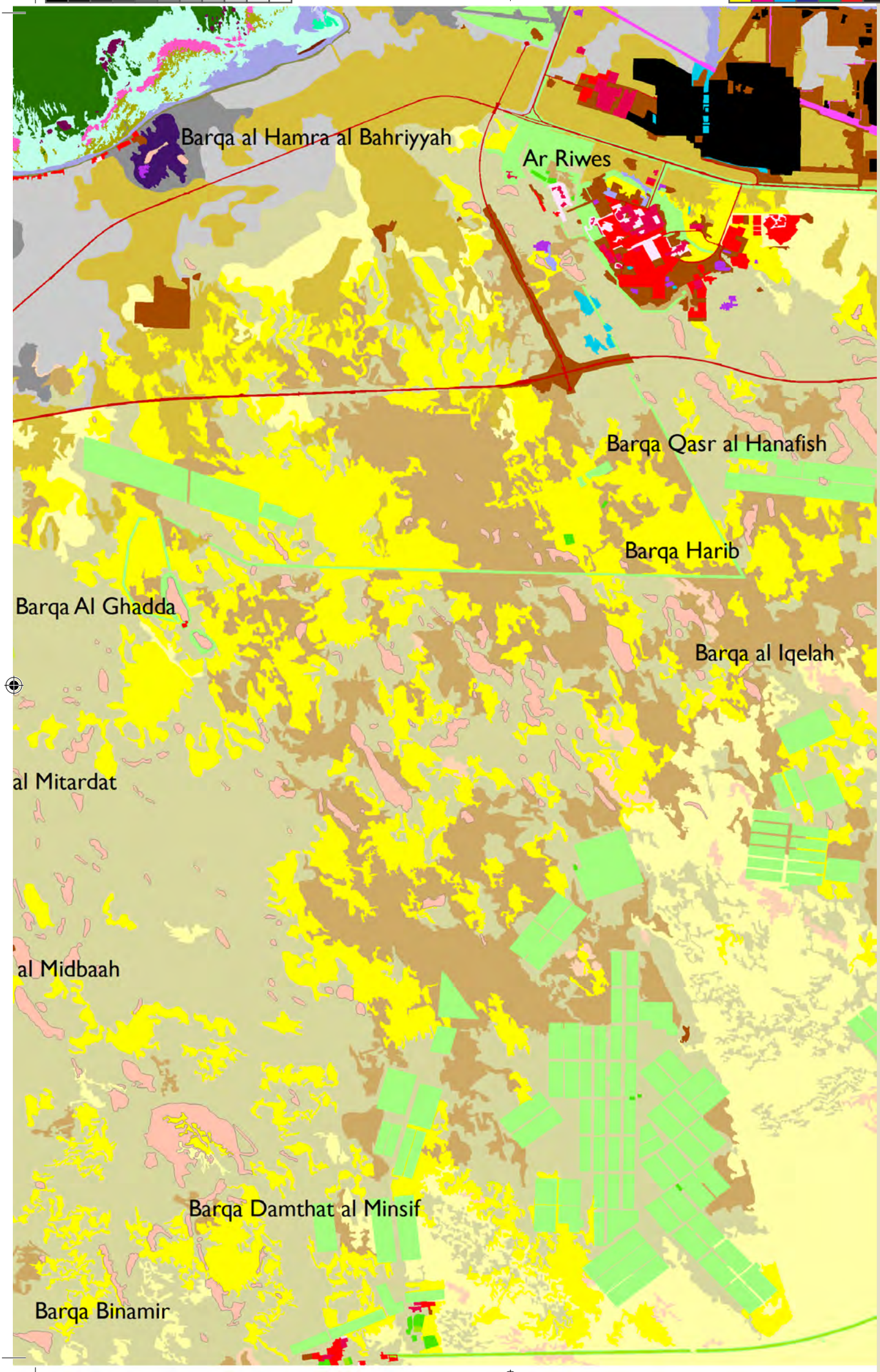
The many barqas or mesas in the Western Region provide clear evidence of former times when the sea level was much higher than it is today. They are flat-topped hills, mostly 10 to 20 metres high, and they have survived because the hard topmost layer has protected the under-lying sediments from erosion, while the level of the surrounding land has been extensively lowered, mostly through wind erosion. Under the influence of the prevailing north-westerly winds, the removal of that material has contributed to the vast volumes of sand in the Empty Quarter.

The upper layer of the barqas, known as calcrete, was laid down in the intertidal zone anything up to ten million years ago, demonstrating that, at times, the sea was once at least 50 kilometres to the south of the present shoreline. The upper crust is composed primarily of cemented calcium carbonate particles, and it became extremely hard.

Hundreds of barqas are found within the Al Gharbia region of Abu Dhabi as depicted on this map, and they provide valuable refuges for a good range of plants and animals. There is a typical plant community on the tops of the mesas, and this includes a curious lily, *Dipcadi erythraea*, that has brown flowers (that are otherwise similar to those of a bluebell). This species survives for very long periods (up to several years) as a bulb buried in the shallow sand on top of the calcrete. After rain the bulbs shoot and flowers are produced in only a week or two.

The calcrete topping of the barqa is often undercut, creating overhangs, holes and crevices that are used by rodents, hares, lizards, snakes, bats and birds. The latter include at least three species of owl, including a subspecies of Little Owl, known as Lileth Owlet, that is endemic to the southern Arabian Gulf. There is some evidence that bats comprise a major part of the food for Lileth Owlets in Al Gharbia.




Barqa al Hamra al Bahriyyah
Ar Riwes
Barqa Qasr al Hanafish
Barqa Harib
Barqa Al Ghadda
Barqa al Iqelah
al Mitardat
al Midbaah
Barqa Damthat al Minsif
Barqa Binamir

ABU DHABI ISLAND

Abu Dhabi Island arose as one of a series of barrier islands along the gently shelving southern shore of the Arabian Gulf. The highest part of the island is close to the seaward shore, and that shelter permitted the development of sabkha from former intertidal flats. Windblown sand gradually raised the level of the island and reduced salinity.
The discovery of water on the island nearly 300 years ago led to the establishment of the first small human settlement, although the water was soon exhausted and other sources had to be called upon.

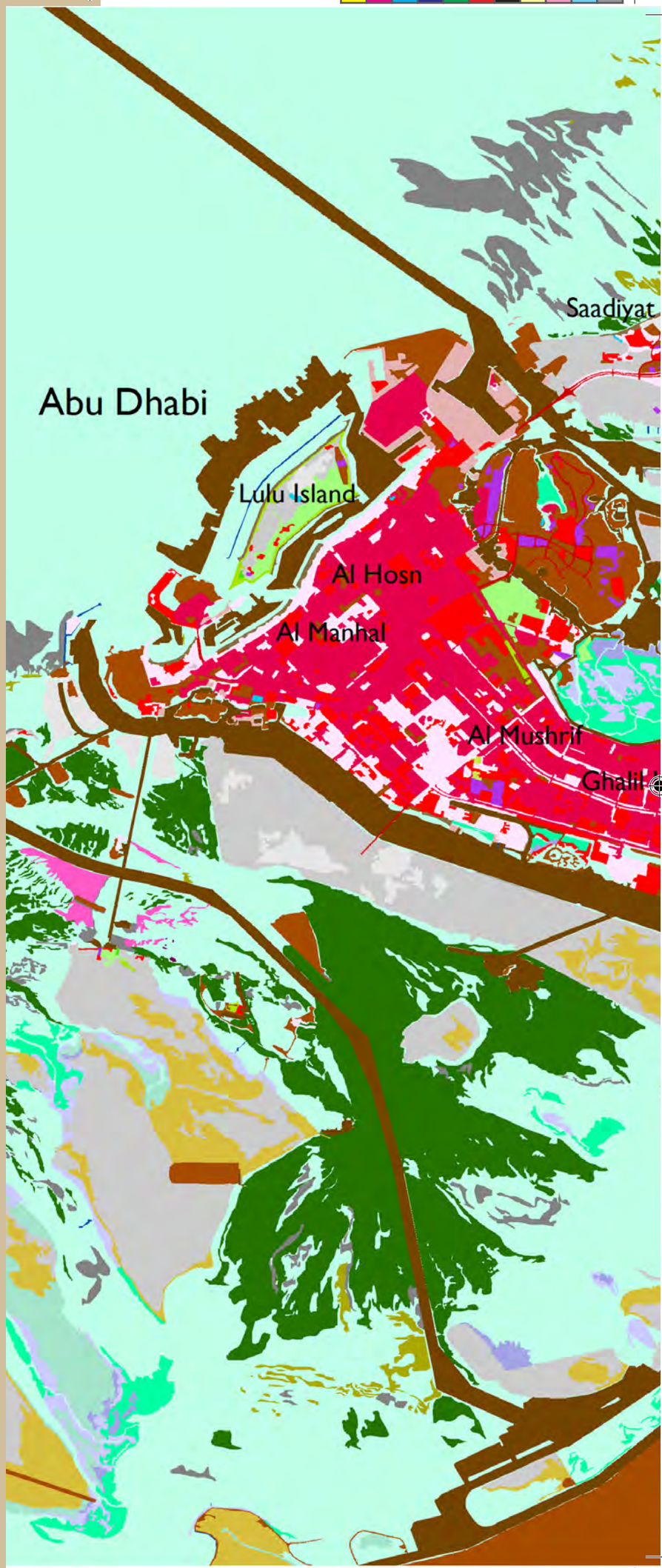
The first residents of Abu Dhabi were primarily seafaring traders and fishermen, but with some dependence of dates and camels. There was a period of prosperity in the first half of the twentieth century, as a result of sharp growth of the pearling industry.

Over the past four decades, Abu Dhabi has seen very rapid development, and it is now an ultra-modern city. The development has brought many benefits but also significant impacts upon the surrounding natural environment.

The urban area of Abu Dhabi has encroached upon adjacent islands and intertidal areas. For example, it is now impossible to determine what habitats were present on the area now occupied by Reem Island without the use of historical satellite imagery. Urbanisation is now spreading rapidly inland, but the coastal zone commands higher prices and there is great pressure for further development.
More highways and bridges are planned, and there is likely to be ever-increasing use of the waterways. Land creation is achieved primarily from dredging the seabed and this has direct ramifications for the marine habitats and wildlife. These changes will require careful monitoring, and this can be accomplished with future updates to the baseline mapping shown here.

The saltmarshes and mangroves situated around Abu Dhabi Island are under threat but new stands of mangroves have been planted and are doing well, although they are increasingly being used for recreation.

The many parks, leisure areas and tree-lined streets on Abu Dhabi Island are clearly shown on the map. These are important for terrestrial species as well as offering peaceful leisure areas for the human population of the island.



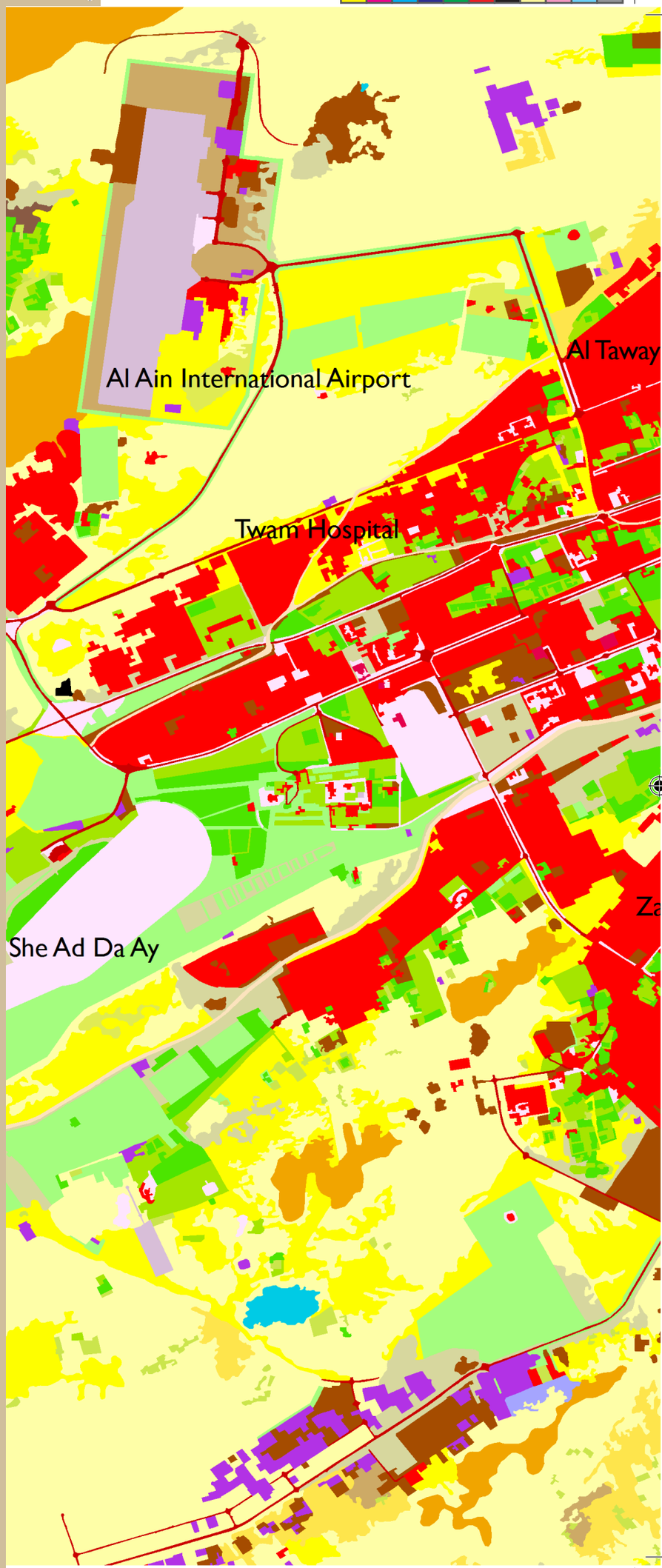
AL AIN

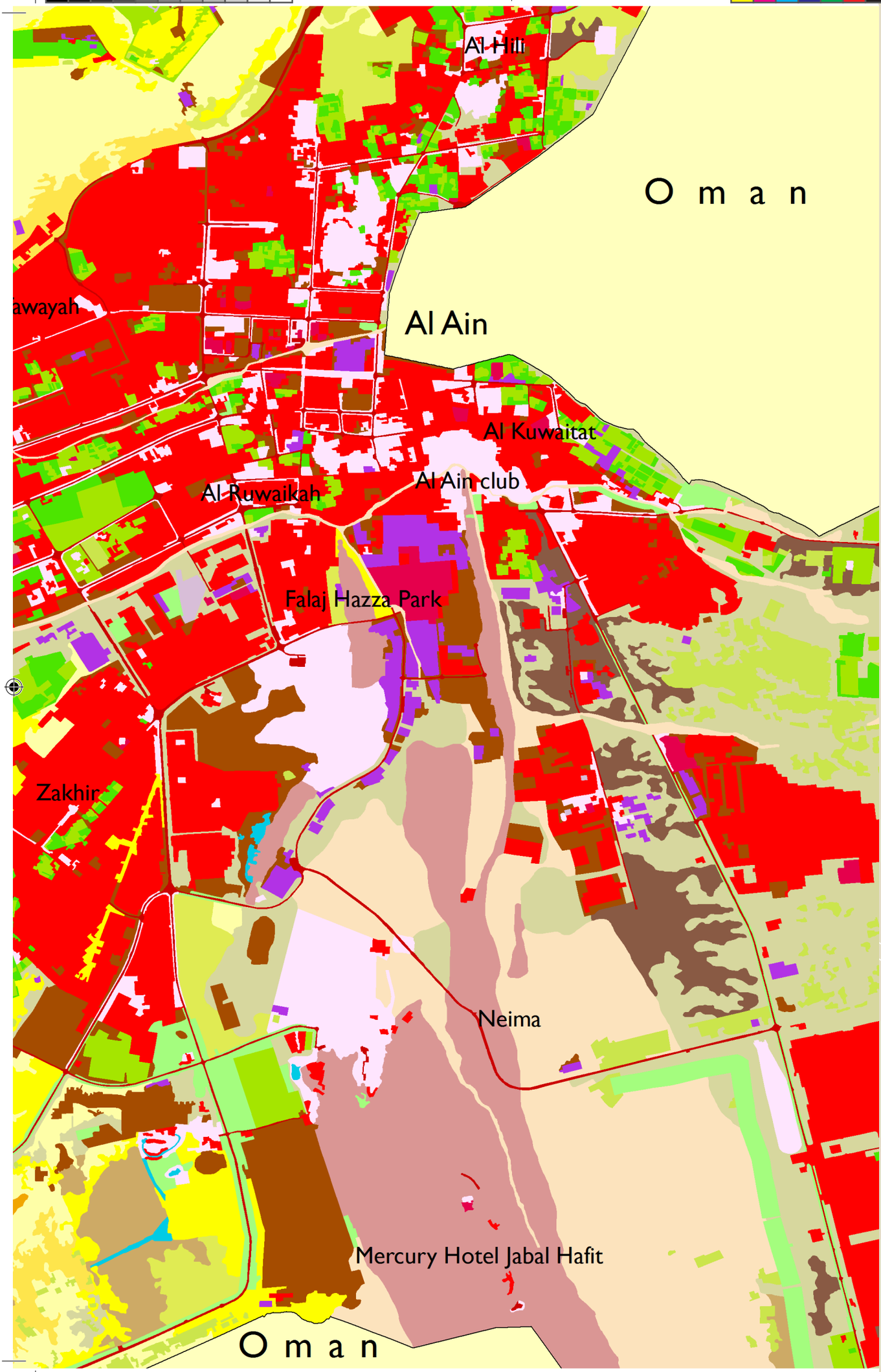
Al Ain has grown very rapidly over the last half-century from a small settlement and trading post. Being close to the Hajar Mountains, it was possible to exploit sources of water and channel it to where it was needed, via the ancient falaj system. This led to the creation of extensive date plantations and farms. The development of the city has been kept low-rise, and there are many parks and gardens. In fact Al Ain is known as the Garden City because of its greenery but it is also famous on account of the impressive inselberg, Jebel Hafit, that rises sharply from the desert plain on the southern flank of the city.

Standing at 1,249 metres, Jebel Hafit has a far higher botanical diversity than anywhere else in Abu Dhabi Emirate. The landscape is harsh, rugged, complex and daunting to walkers and climbers. Uplift, weathering and erosion have created a diverse range of habitats within the mountains, including deep shady wadis with ephemeral pools. These help to support a wide range of birds, mammals and reptiles.

Jebel Hafit is the only refuge in Abu Dhabi for the endangered Arabian Tahr. Recent habitat loss and other pressures have seen the global population of this wild mountain goat decrease to less than 2,000. It is now only found in remote mountain areas with steep or almost vertical exposures of bare rock. The species still survives on Jebel Hafit but the animals may have become reliant on one or two man-made water sources.

Al Ain Zoo was founded in 1968 and has undergone a massive programme of expansion and improvement since the turn of the century. It is well known for its breeding programmes, often exchanging animals with other breeding enterprises. It has been heavily involved in captive breeding of the endangered Houbara Bustard and Arabian Oryx, and their successful release into the wild.



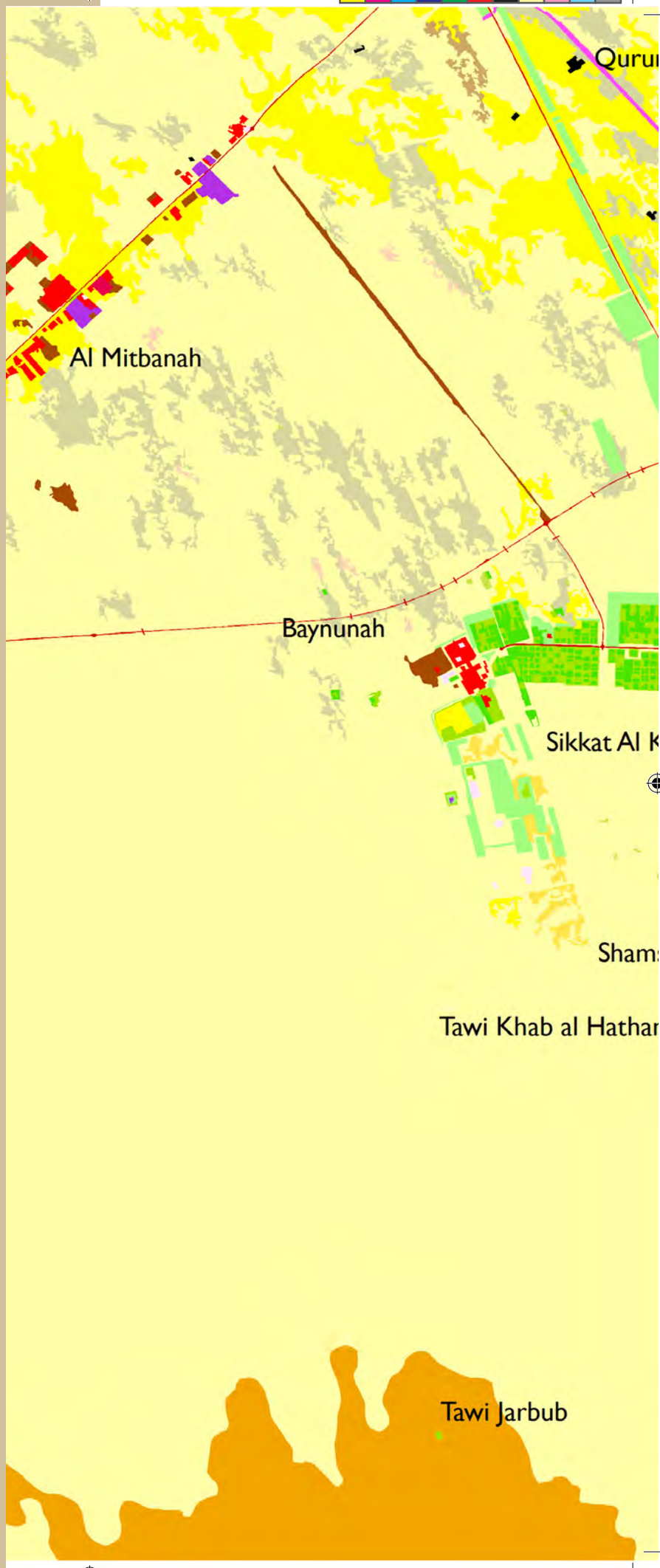

Al Hili
O m a n
awayah
Al Ain
Al Kuwaitat
Al Ain club
Al Ruwaikah
Falaj Hazza Park
Zakhir
Neima
Mercury Hotel Jabal Hafit
O m a n

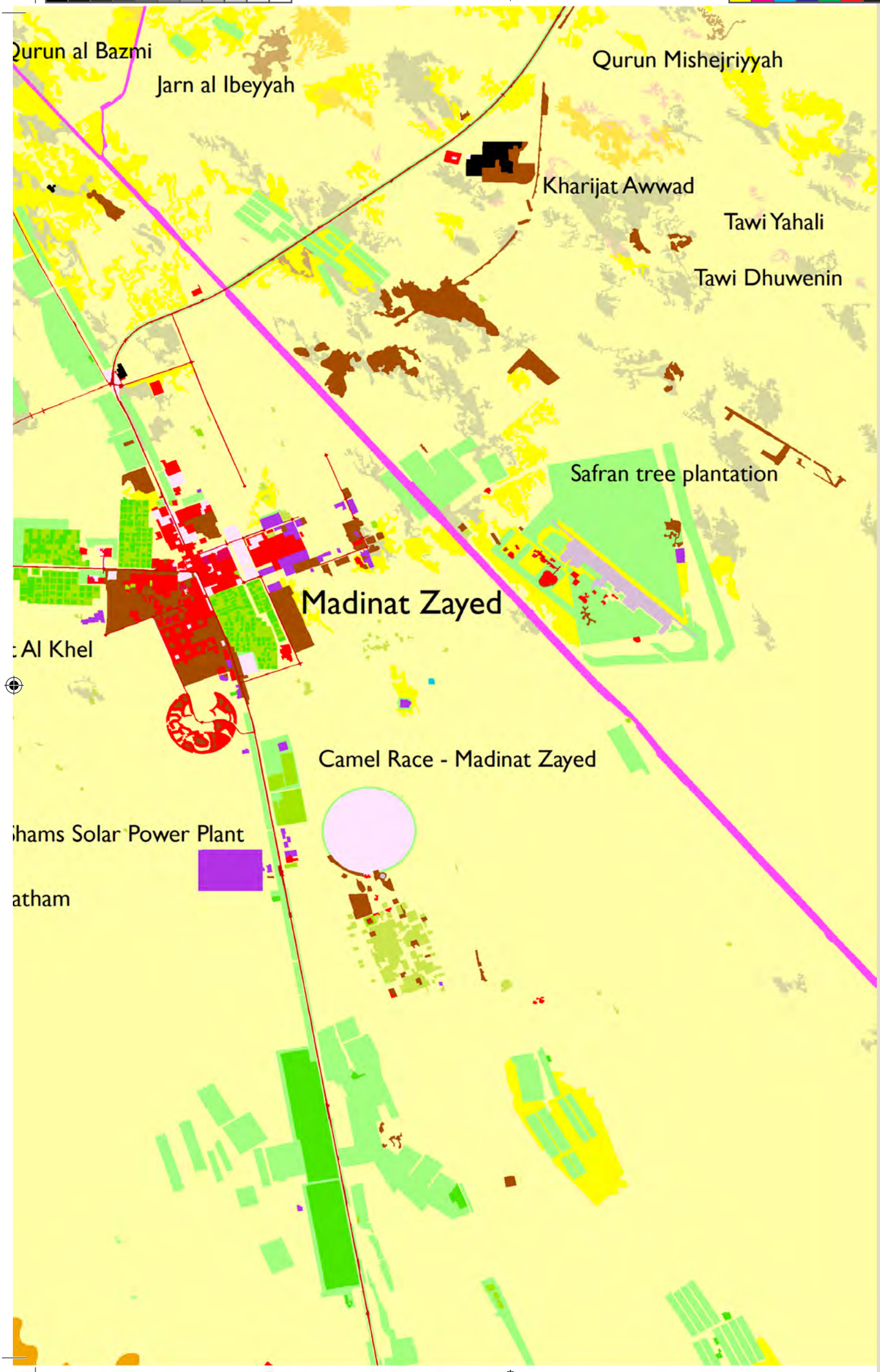
MADINAT ZAYED

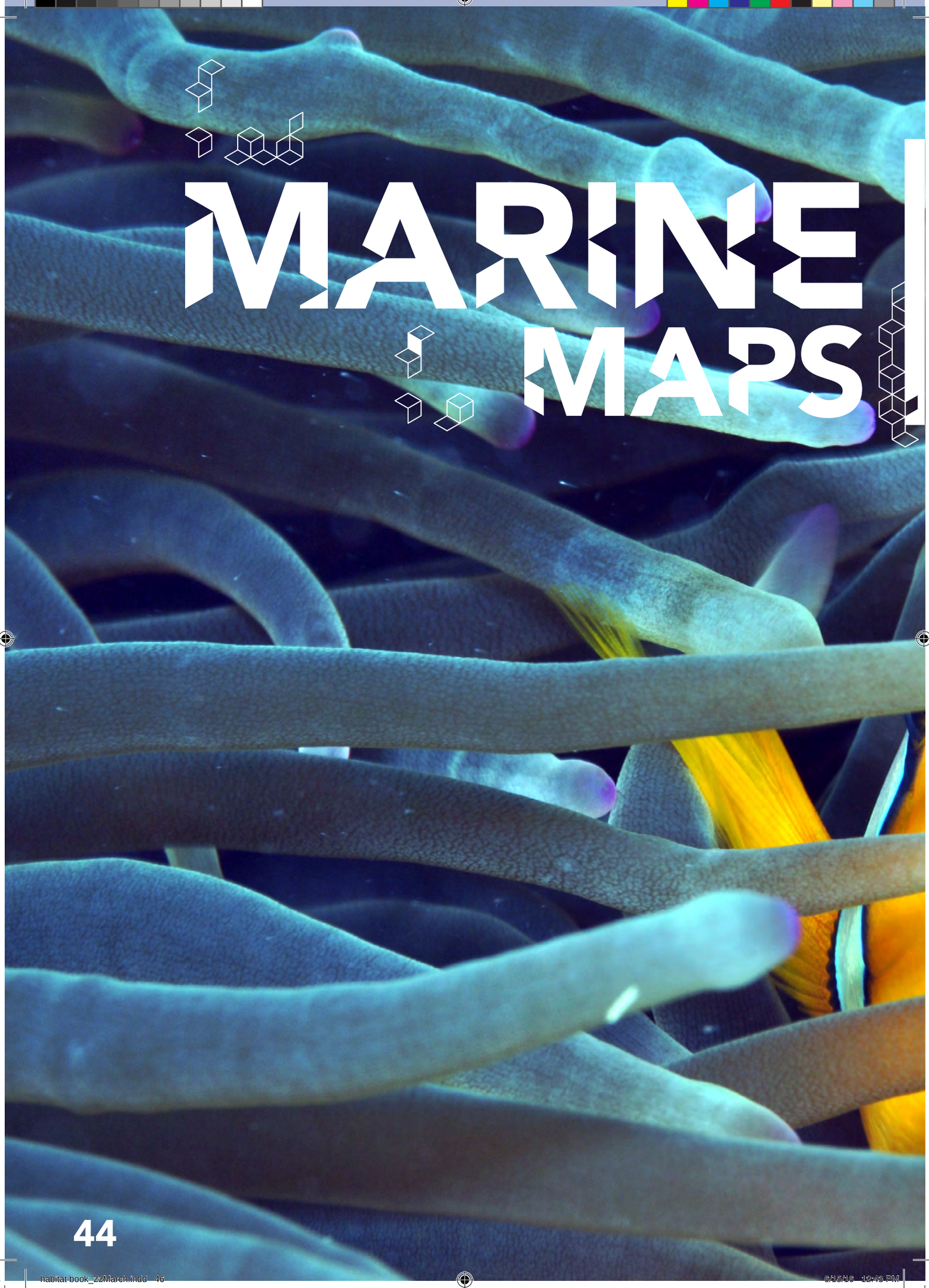
Madinat Zayed is the largest town in Al Gharbia, the western region of Abu Dhabi Emirate, and is situated close to the Shams-1 solar power station, opened in 2013, which is the world's largest operating concentrated solar power plant. This uses arrays of parabolic reflectors, over an area of 2.5 square kilometres, to heat molten salt that drive steam turbines, producing up to 100 megawatts of power. Photovoltaic plants are also online at Masdar.

Al Gharbia constitutes 71% of the land area of the UAE, and is home to some of the rarest wildlife in the UAE, including Arabian Oryx, Rüppell's Fox, gazelle, Desert Eagle-owl, Long-legged Buzzard and Golden Eagle. The marine area supports populations of Greater Flamingos, turtles, dolphins and the endangered dugong.

Just 10% of the UAE population live here within the seven cities of the region, but it is becoming a popular tourist destination with several attractive hotel resorts, including one on Sir Bani Yas Island. This island has a large wildlife reserve and a variety of habitats and unspoilt surroundings that attract many migratory birds.




Qurun al Bazmi
Jarn al Ibeyyah
Qurun Mishejriyyah
Kharijat Awwad
Tawi Yahali
Tawi Dhuwenin
Safran tree plantation
Madinat Zayed
Al Khel
Camel Race - Madinat Zayed
hams Solar Power Plant
atham



A total of 13 different categories have been used to extensively map Abu Dhabi Emirate waters using satellite imagery.

From coral and seagrass, to mangroves, saltmarsh and intertidal mud flats, the mapping of each habitat allows the impact of future coastal developments to be carefully monitored. Any unexpected increase in habitat can also be identified, such as the coral heads mapped near Silaa. Such discoveries can allow decision-makers to consider revising the boundaries of protected areas such as the Al Yasat Marine Protected Area (MPA). These areas are managed by EAD and are already showing positive benefits for habitats and species.

The preservation of Abu Dhabi's marine habitats are crucial to the existence of the endangered Dugong, hundreds of bird species, and assisting with recovery of fish stocks that have declined by 80% in recent years.

UNESCO-DESIGNATED MARINE BIOSPHERE RESERVE

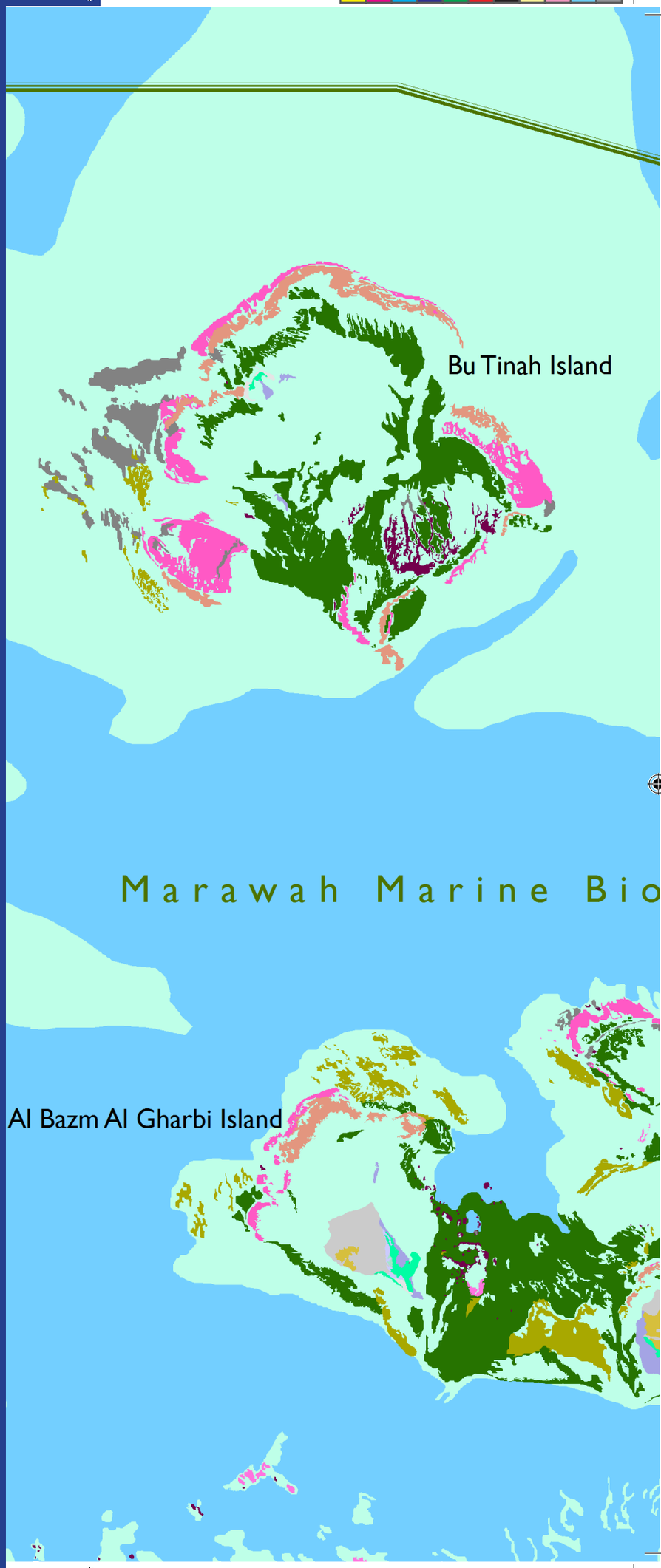
Bu Tinah and the surrounding islands lie within the Marawah Marine Biosphere Reserve, the only UNESCO designated marine biosphere reserve in Abu Dhabi, and this was established in 2001.

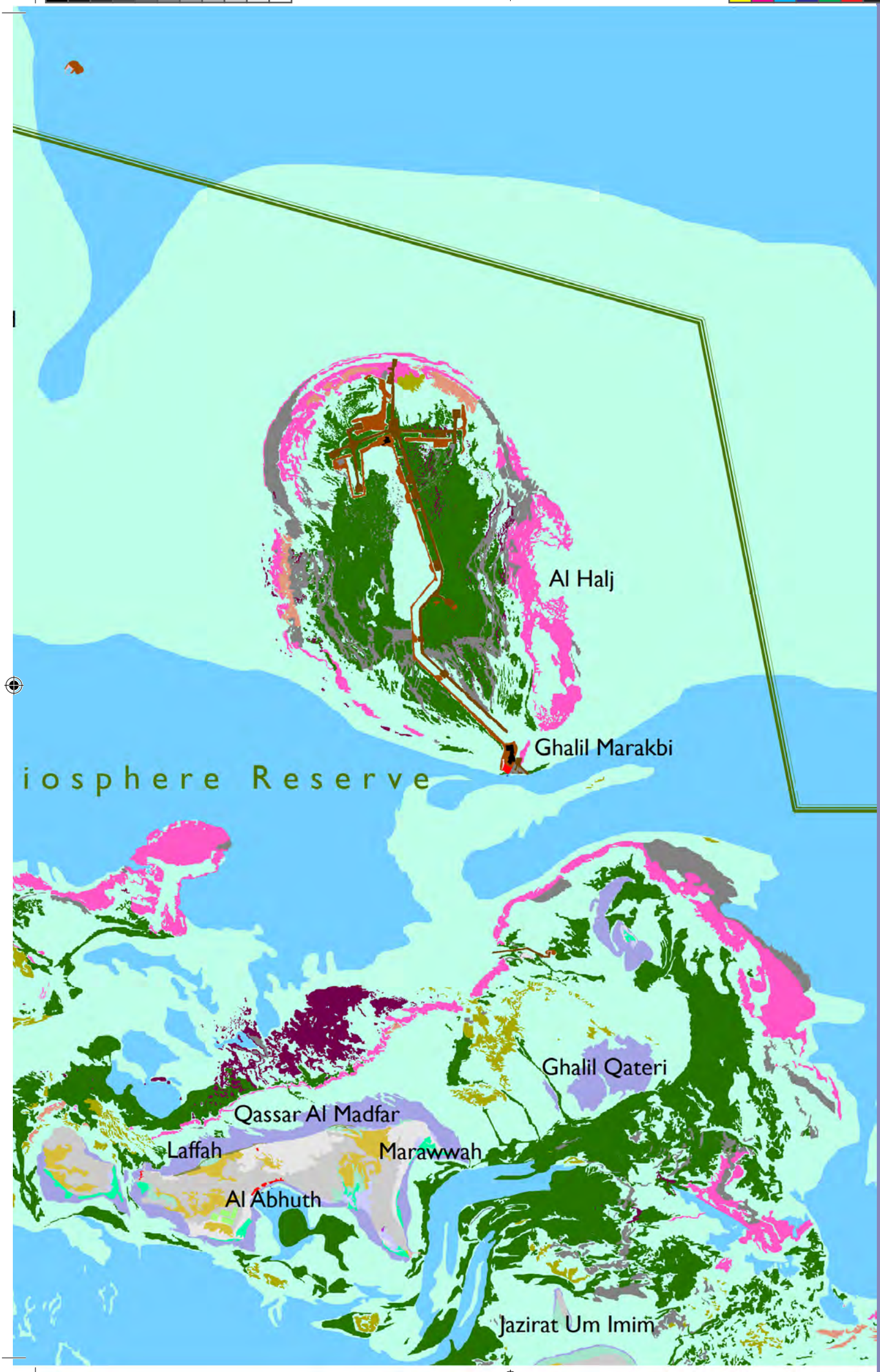
The islands here are no higher than 2 to 3 metres above sea level, and some of them join together at low tide.

The lack of human intervention in this area has allowed wildlife to flourish, and access to the islands is closed to the public.

It is a small archipelago, rich in biodiversity due to the abundance of coral and seagrass that support a variety of fish species, dugongs and turtles.

16 coral species are recorded here, and survive in highly saline and warm waters that would kill other coral species. The area is also rich in mangroves supporting varied species of birds.



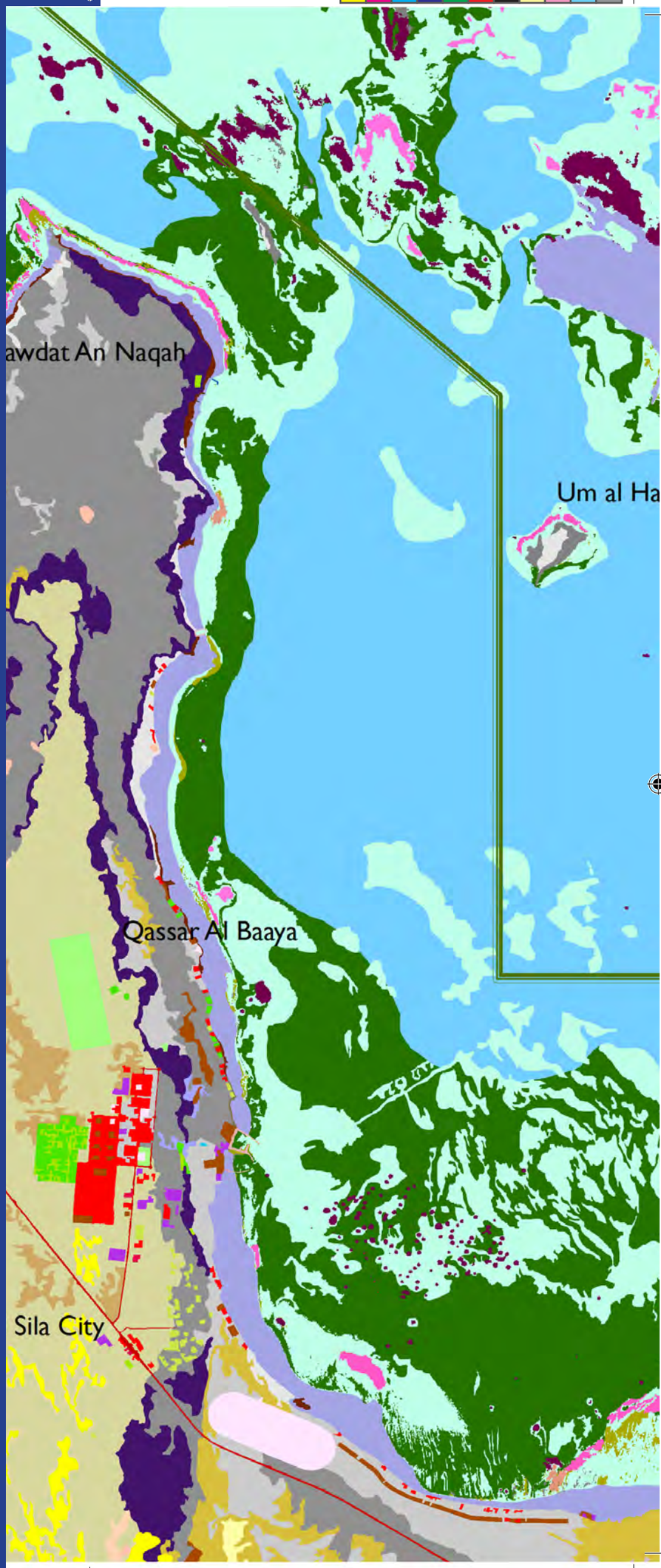

Al Halj
Ghalil Marakbi
iosphere Reserve
Ghalil Qateri
Qassar Al Madfar
Laffah
Marawwah
Al Abhuth
Jazirat Um Imim

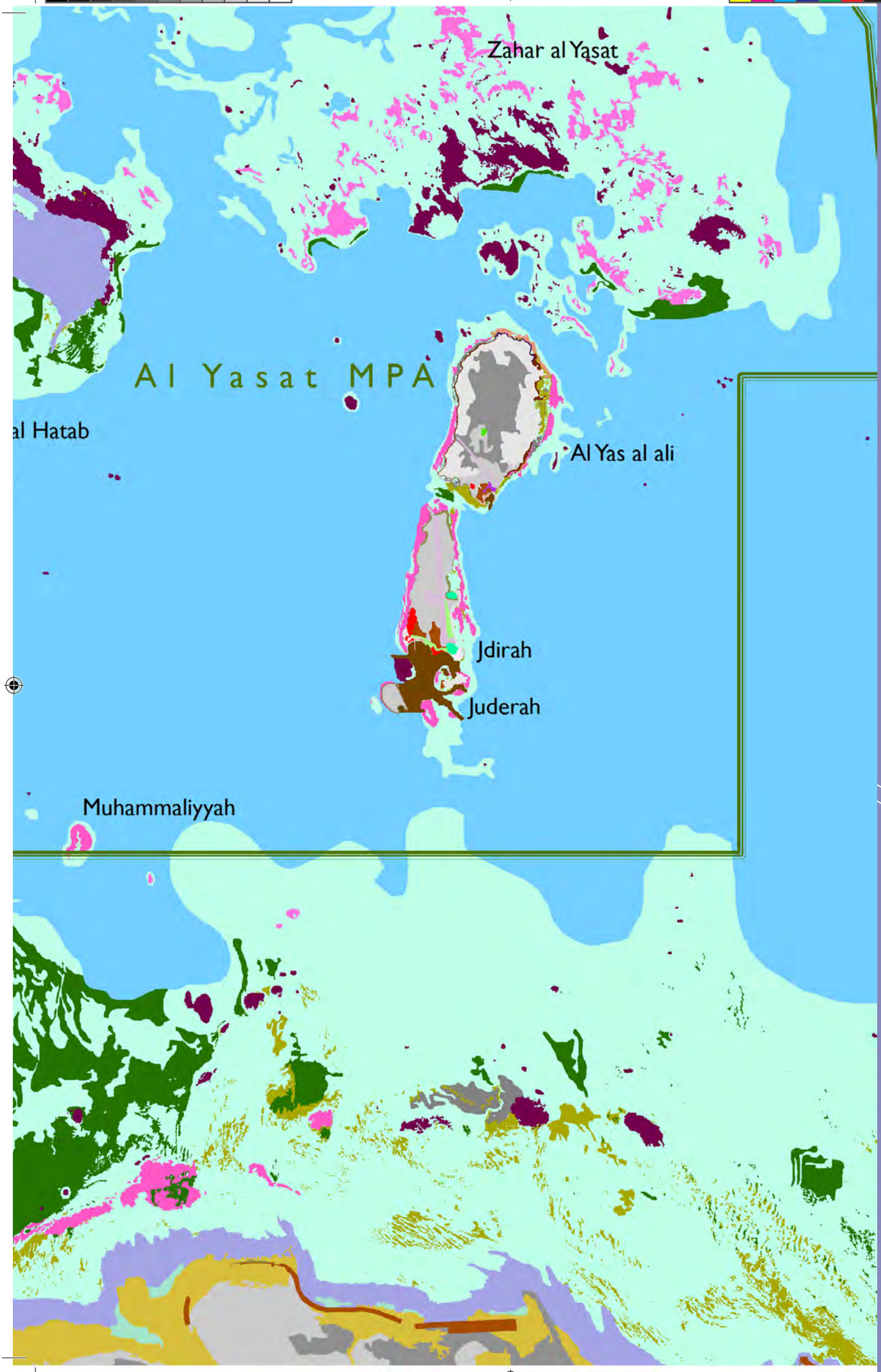
CORAL & SEAGRASS

Diverse habitats such as shallow sandy bays and open coasts all support seagrass growth, which is fundamental to the marine ecosystem of Abu Dhabi. The IUCN considers Dugongs to be vulnerable to extinction, although numbers are growing in Abu Dhabi. This growth is heavily reliant on seagrass beds which are the main source of food for Dugongs. Seagrass beds also support many species of fish and diverse communities of invertebrates.

Coral species are less diverse in the Gulf than those found in Australia's Great Barrier Reef, with staghorn *Acropora* and boulder coral *Porites* being the main reef-building species here. They are threatened by rising seawater temperatures and salinity levels, with staghorn corals being the most susceptible. Coral reefs are the first ecosystems to show the impact of global climate change. The coral communities of Abu Dhabi have changed dramatically over the last 2 decades. The cover of branching *Acropora* species has declined dramatically since 1996. There has been an increase in the frequency and prolongation of positive seawater temperature anomalies resulting in a series of bleaching and associated mass mortality events. The coral communities are now dominated by more resilient *Favids and Poritids*.

Extensive seagrass beds have been identified to the south of the Al Yasat MPA together with reef heads at a depth of about two metres. This discovery will give rise to further conservation measures and an opportunity to preserve the wealth of marine habitats in these coastal waters.




Zahar al Yasat
Al Yasat MPA
al Hatab
Al Yas al ali
Jdirah
Juderah
Muhammaliyyah

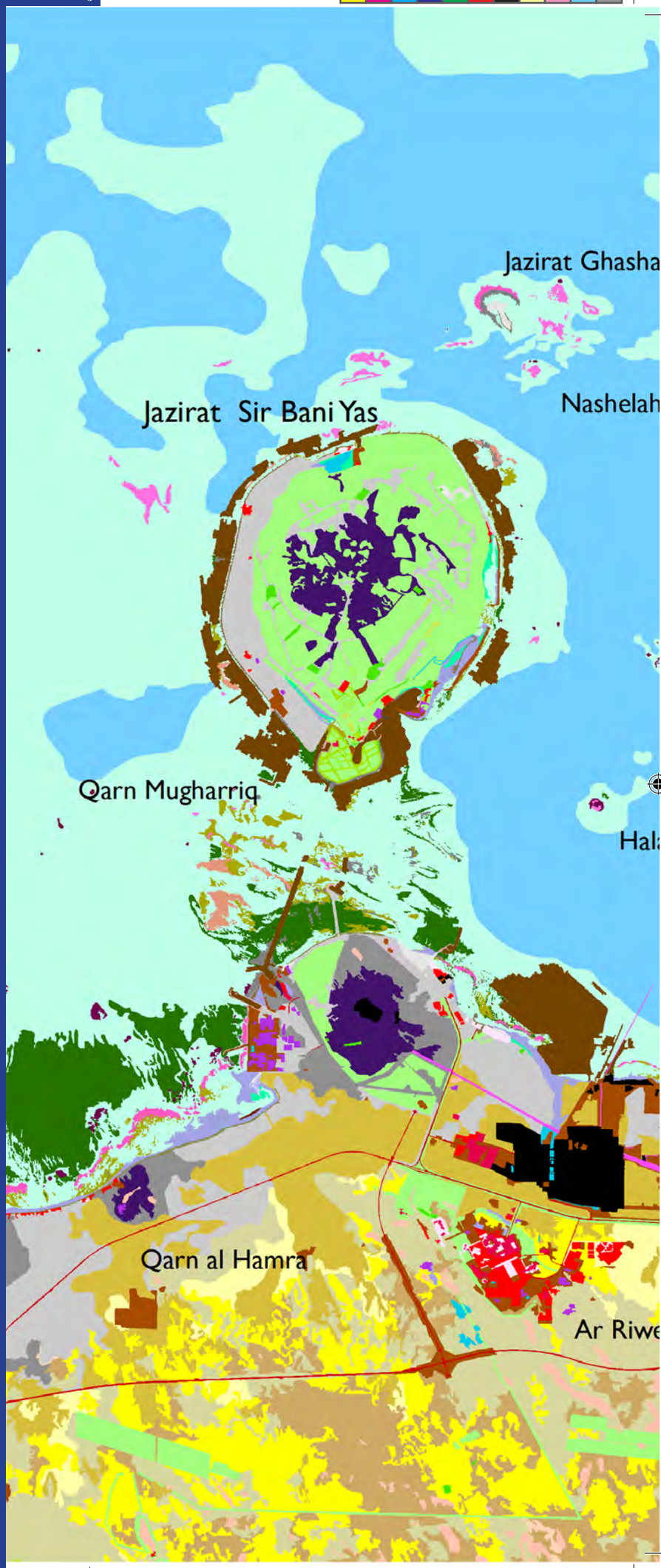
ISLANDS

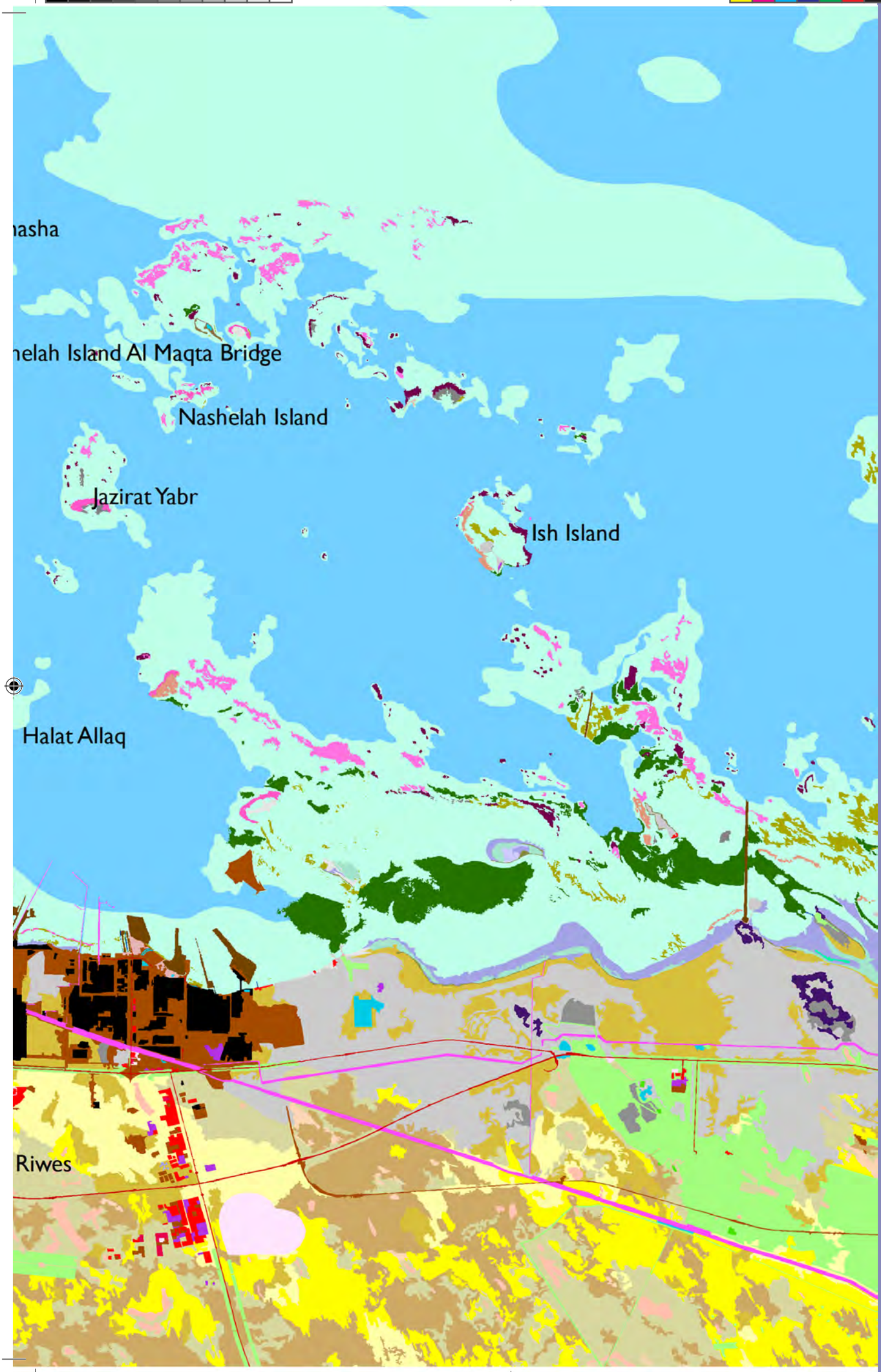
Abu Dhabi contains almost 200 islands. Most of these are based on carbonate sediments but some of them, such as Sir Bani Yas and Delma, arose as diapiric salt domes, in which the pressure of over-lying sediments forced semi-molten salt to move upwards and break the sea surface. The salt brought with it a range of other geological materials. The diapiric islands are now surrounded by areas of fringing reef and seagrass habitats.

Sir Bani Yas Island is home to many wildlife species, both native and exotic, including introduced Arabian Oryx, gazelles, giraffes, and cheetahs. Marine species such as turtles and dolphins occur there naturally and benefit from the protection afforded by the Arabian Wildlife Park that covers half of the island. The park is constantly evolving with re-vegetation and removal of man-made features, with an effort to provide visitors with details of breeding and conservation programmes.

The Al Yasat MPA, Marawah Marine Biosphere Reserve and Bul Syayeef are other protected areas that cover Abu Dhabi's islands and marine habitats, safeguarding the future of Dugongs, Hawksbill Turtles, Desert Hares, migratory birds and uncommon plants.

Islands play a significant role in the conservation of Abu Dhabi's flora and fauna. The general isolation of islands protects their inhabitants from threatening processes occurring on the mainland.



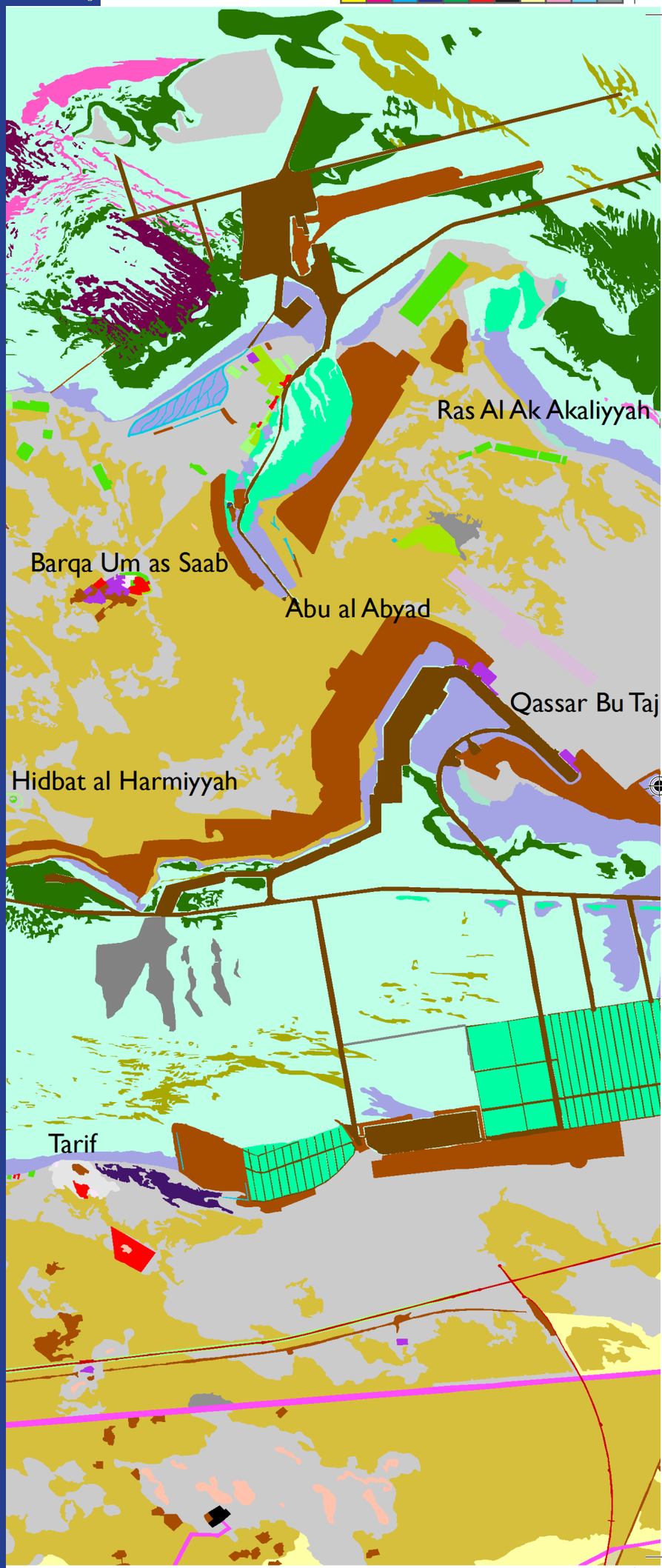

nasha
nelah Island Al Maqta Bridge
Nashelah Island
Jazirat Yabr
Ish Island
Halat Allaq
Riwes

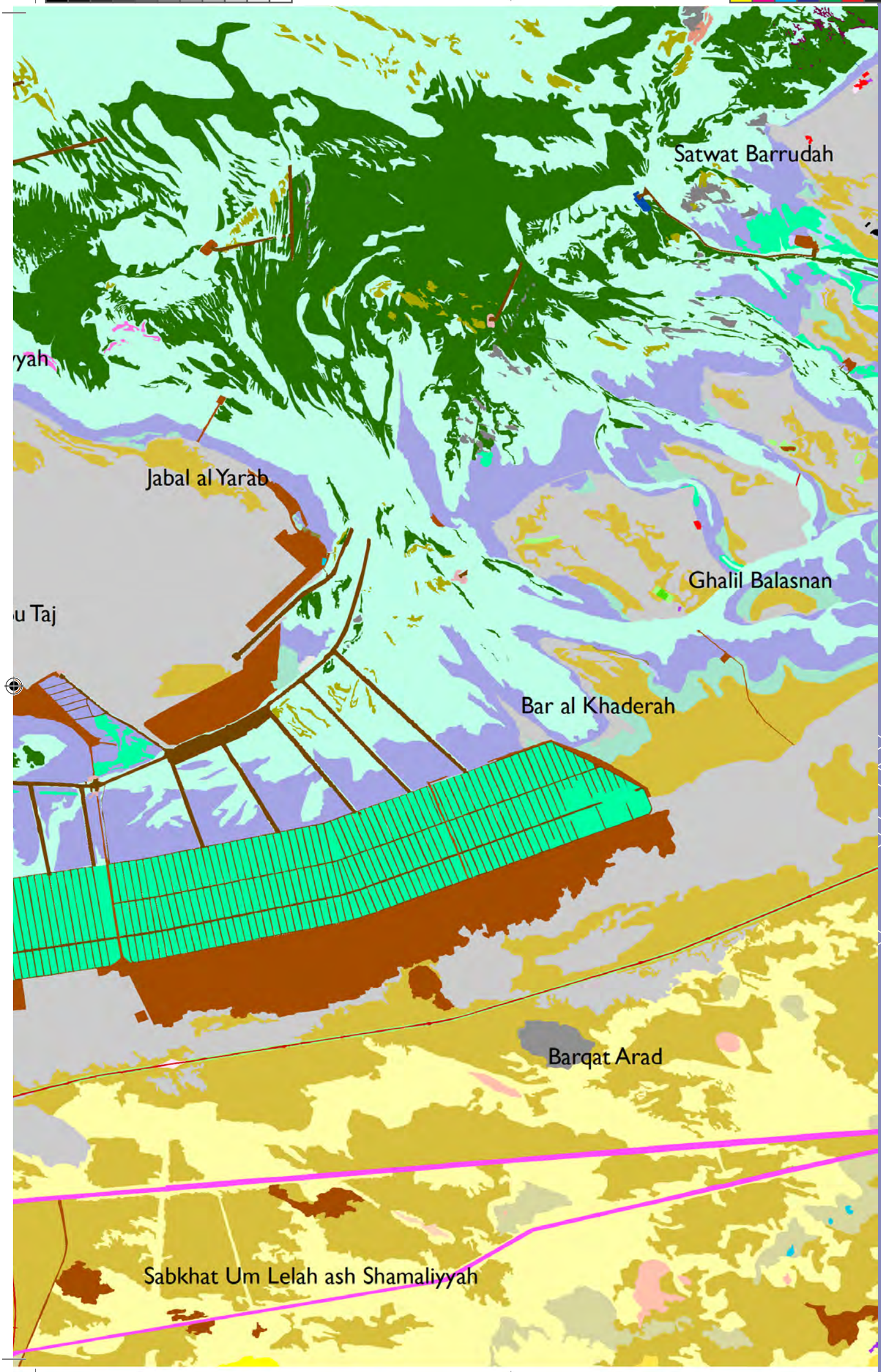
THE COASTAL ZONE

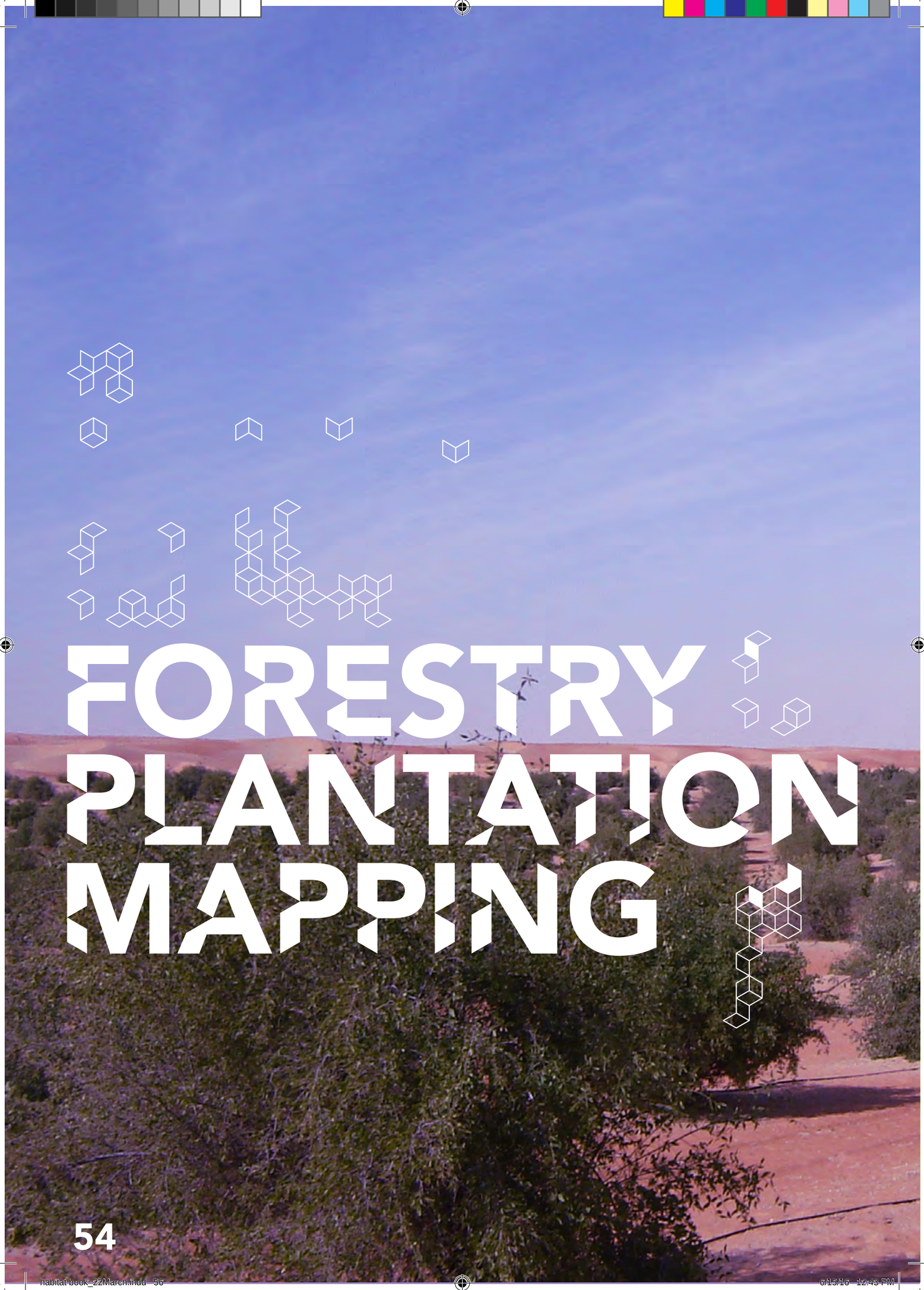
The Grey Mangrove, *Avicennia marina*, is a native species found extensively along the UAE coast of the Arabian Gulf. Mangroves are found in the middle part of the intertidal zone and they play a key role in reducing the effects of coastal erosion due to storms, currents and wave action.

To extend the natural stands, 2 million mangroves had been planted by EAD by the end of 2014 and this programme continues. The main intention is to prevent loss of habitat due to the intensive development taking place along Abu Dhabi's coastlines. As can be seen in this map, they have been planted in long strips in an effort to preserve the coastline.

Mangroves sequester carbon, storing it both within the plants themselves and within the accumulating sediment beneath. The reduction of atmospheric carbon dioxide helps to reduce the effects of climate change. Mangroves also remove trace metals and other pollutants in seawater, acting as a filtering system. Many species of fish, molluscs and crustaceans breed in these mangrove forests, and they also provide habitat and food for nesting and migratory birds.



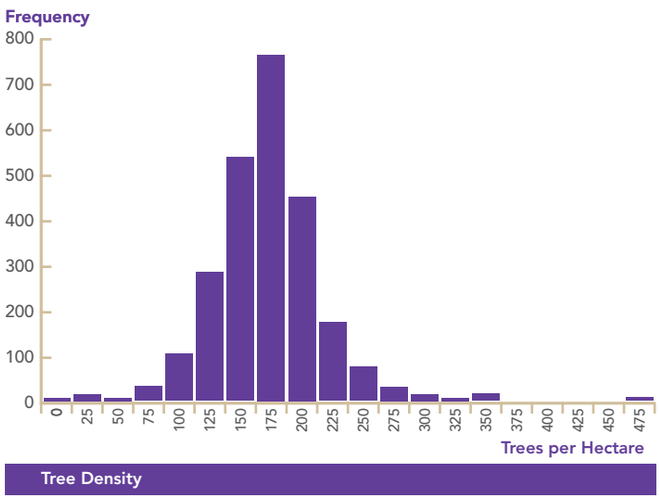




FORESTRY PLANTATION MAPPING

FORESTRY PLANTATION MAPPING

As part of the habitat programme a more detailed study was undertaken to map Abu Dhabi's Forestry plantations in detail in 2014/2015 using remote sensing methods to identify 25 million trees in two thousand five hundred plantations that were identified from the habitat mapping.

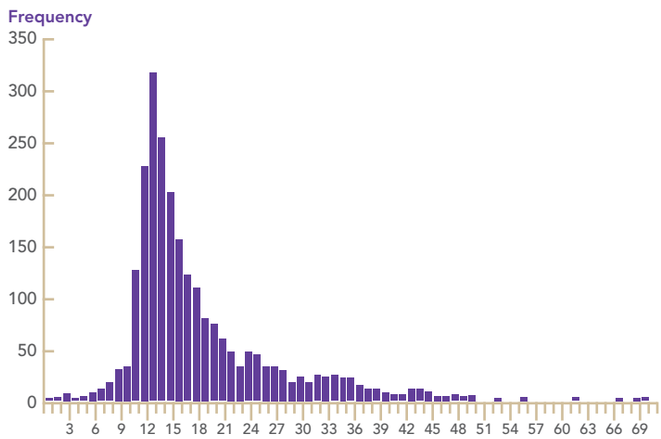


Tree Density

The tree health and species can be determined using a combination of spectral property assessment and ground truthing methods to validate the mapping, ensuring a mapping accuracy of 74%. The following species were mapped; *Acacia tortilis, Salvadora persica, Conocarpus spp, Prosopis cineraria, Phoenix dactilyfera, Prosopis juliflora, and Zizyphus spina-cristi.*

The mapping was performed using DigitalGlobe WorldView-2 imagery, pan-sharpened to 50cm resolution, allowing tree crowns to be plotted with a diameter of more than two metres.

Vegetation cover fraction values were measured to calculate the vegetated area as a percentage of each plantation. The median value is 77% from a plantation in the well irrigated Liwa Oasis.



Vegetation Cover Fraction

FORESTRY PLANTATION MAPPING

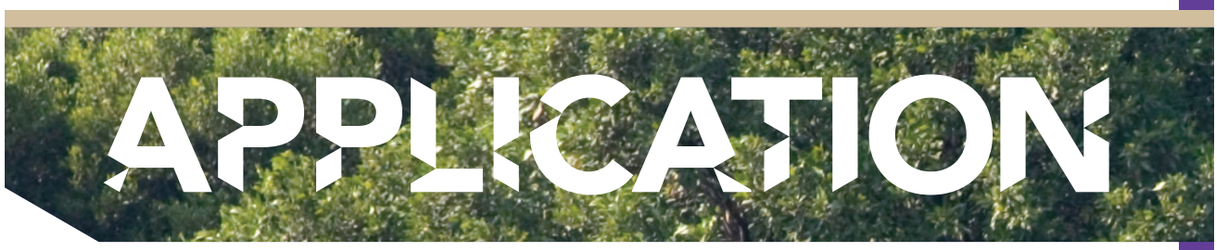
Using remote sensing methods, the forestry plantations can be mapped as a single baseline "snapshot" in time, allowing future mapping processes to monitor and record areas of vegetation stress. This will allow for effective management practices to be employed to improve the condition of trees, as well as increasing the efficiency of water use.

Throughout these examples, an average Soil Adjusted Vegetation Index figure of 0.15 was used. Trees (and plantations) with a figure lower than 0.15 were deemed to be of poor health following information taken from the ground truth surveys.

As shown in the maps on the following page, we can calculate health values associated with each tree crown.


N
Poor Health
Low Health
Medium Health
Good Health
Very Good Health


N
Poor Health
Low Health
Medium Health
Good Health
Very Good Health



This powerful data set is allowing environmental decision making to be more objective and quantifiable. The data produced by this project will make UAE government targets easier to measure and implement, and will mean that the decisions surrounding policies are wholly justifiable.

The data set will also allow the Abu Dhabi government to focus efforts in protection and conservation in a way that has not been possible before. For example, correlation with other data on migration patterns and sightings can provide a very detailed understanding of the habitats of endangered species. Such information is vital to mitigate against harmful human development and to help with sustainability.

Accessing Data

The map data is being delivered using the Environment Agency-Abu Dhabi BeAtty "My Environment" App and the enviroportal that can be accessed via a web browser. This will allow decision makers access to many data layers, including protected areas and Forests, Marine and Terrestrial habitats, all of which can be overlaid on satellite imagery acquired between 1972 and 2014.

Internal stakeholders have full access to the habitat map, which will improve their productivity. For example, the field biodiversity survey teams will be able to access the map from their mobile devices meaning that they can easily target areas of interest. This presents a significant time and cost saving opportunity as field based survey activities become more efficient.

Financial Gain

The monetary costs of completing a very high resolution satellite habitat map compared to traditional field survey methods are very difficult to measure. But it is known that a field survey exercise of this size would take substantially longer than the 20 months that was the duration of the satellite mapping program. Estimates are in the region of 7 years if a large field survey team of 20 to 30 people were to be deployed. The costs of resourcing such an exercise would far outway the costs of a satellite mapping solution. Additionally a field-based approach would not provide the "snap shot" in time provided by this project.

Increased Efficiency

Environment Agency-Abu Dhabi has a responsibility for managing environmental permitting. The permitting process involves an environmental impact assessment that considers the direct effects of any human activity at a specific location, as well as the in-direct effects on the surrounding area.

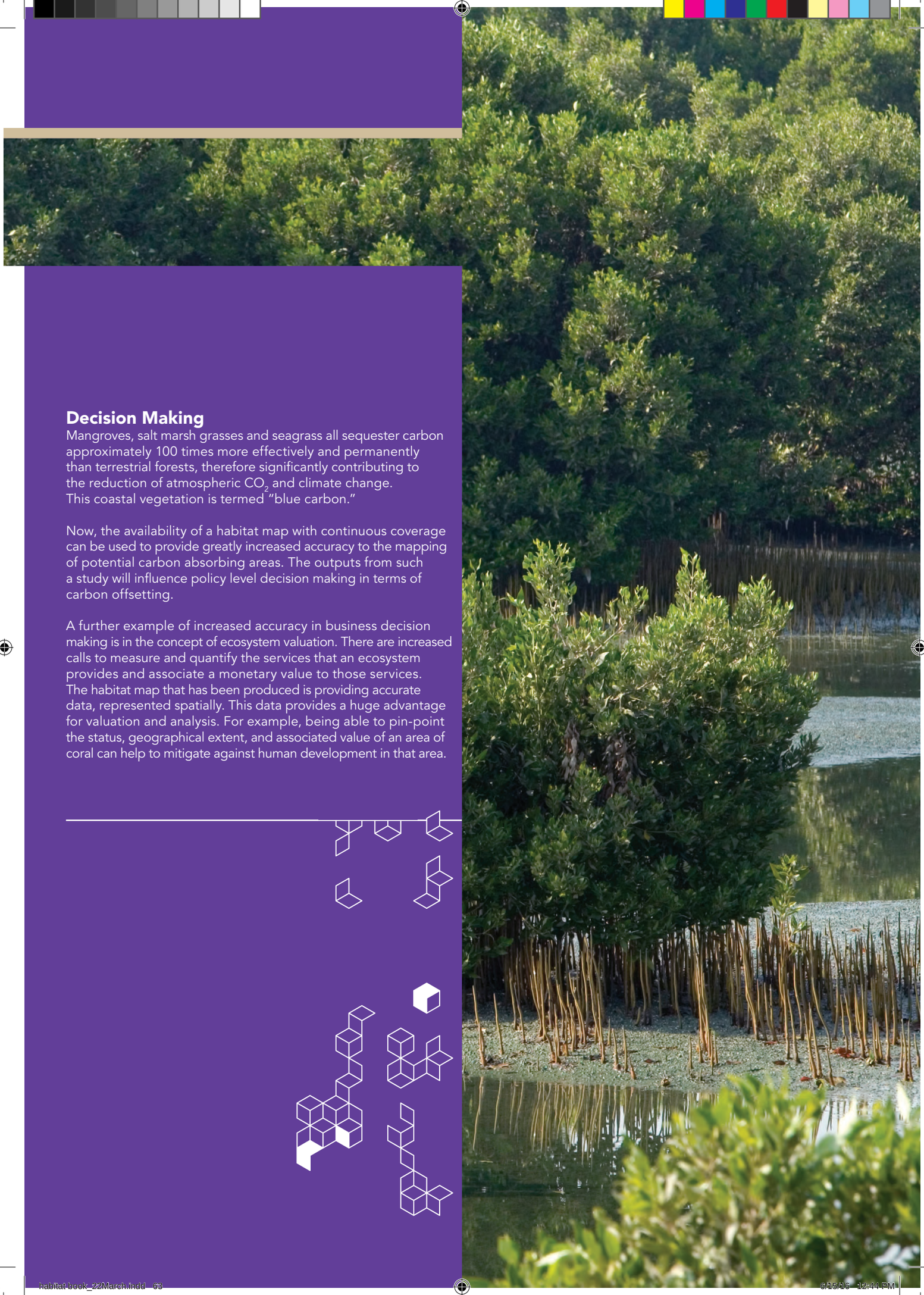
The permitting process will be greatly eased, as the satellite derived habitat mapping means that the effects of construction on a specific habitat are directly quantifiable at a specific location. The habitat map will also allow modelling of the effects upon the surrounding area, as well as the cumulative impacts of development over time.

Decision Making

Mangroves, salt marsh grasses and seagrass all sequester carbon approximately 100 times more effectively and permanently than terrestrial forests, therefore significantly contributing to the reduction of atmospheric CO_2 and climate change. This coastal vegetation is termed “blue carbon.”

Now, the availability of a habitat map with continuous coverage can be used to provide greatly increased accuracy to the mapping of potential carbon absorbing areas. The outputs from such a study will influence policy level decision making in terms of carbon offsetting.

A further example of increased accuracy in business decision making is in the concept of ecosystem valuation. There are increased calls to measure and quantify the services that an ecosystem provides and associate a monetary value to those services. The habitat map that has been produced is providing accurate data, represented spatially. This data provides a huge advantage for valuation and analysis. For example, being able to pin-point the status, geographical extent, and associated value of an area of coral can help to mitigate against human development in that area.



FUTURE WORK

The habitat mapping project serves as a ground breaking baseline, completed in rapid time compared to conventional methods using ground based teams that may have taken several years to complete as opposed to 20 months using remote sensing techniques. The processes involved allows for future updates to be completed using similar techniques to track changes in habitats and enforce effective management practices to protect the environment from urban encroachment or industrial activities.

Rapid modelling can now take place using the completed mapping to establish the impact on surrounding habitats following construction of facilities via Environmental Impact Assessment reports that will consider the direct impact of human intervention at a certain location, and the indirect effects on surrounding areas.

Satellite mapping change detection practices can be used to quickly establish change in focused areas such as the Marine Protected Areas established by the Environment Agency to protect marine wildlife.

Identifying new habitats such as the coral heads identified near Sila provide EAD with important decisions to consider regarding modification of existing protection area boundaries to effectively protect these important habitats in order to sustain wildlife numbers.

The mapping methods employed in the creation of these maps for Environment Agency-Abu Dhabi can be employed in other countries and neighbouring Emirates which could effectively standardise the mapping products, potentially helping to dictate policies across border areas where wildlife are free to migrate but require a concerted effort to preserve their habitats, irrespective of the governing entity.

Abu Dhabi has established an initiative under Abu Dhabi Systems and Information Center (ADSIC), called Abu Dhabi Spatial Data Infrastructure (AD-SDI), empowering Abu Dhabi government and society with convenient, open access to high quality and up-to-date geographic information and spatially enabled e-government services as a vision to all Abu Dhabi Government entities. This initiative dramatically reduces duplication of mapping efforts, aligns projects and promotes, facilitates, coordinates and supports the development of dynamic, entrepreneurial, and flexible geospatial enabling environment as its mission, in meeting the needs of individual public-sector agencies across Abu Dhabi Emirate.

There are increasing requests to measure and quantify the services that ecosystems provide, and to associate a monetary value to those services. The habitat map is providing accurate data, presented spatially, thus providing a huge advantage for valuation and analysis. It is now possible to pinpoint the status, geographical extent and associated value of an area of coral to help to mitigate against development in this area. The mapping database can be used as input into MARXAN software that is used as part of the process to design marine and terrestrial reserves worldwide. MARXAN provides a unique method for designing reserves that is systematic and repeatable.

Follow up projects, such as the Forestry mapping project, can be carried out utilising newly acquired satellite imagery that has also been used to update the habitat map. Constantly evolving satellite technology will ensure that improvements to imagery resolution will decrease the minimum diameter value of tree crowns, allowing smaller trees to be mapped. Improvements in positional accuracy will require less ground control points to ensure the accuracy of plotted trees and other features.

As has already been shown, mapping the Abu Dhabi Emirate using remote sensing techniques has not only developed a fundamental baseline dataset, but will allow for inevitable expansion and advancements upon these existing technologies.

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PHOTOGRAPHY REFERENCE TABLE

PAGE	Photograph Title	Photograph Owner
Cover	Al Wathba Reserve	EAD
02	View of sand sheets and dunes with trees	Shutterstock
04	View of mega-dunes and Jebel Hafeet	Nautica
	Coral reef in Al Dabiyah	EAD
06	Sand dunes by Xavier Eichaker	EAD
09	Ground truthing for map verification	Nautica
10	View of mega-dunes and Jebel Hafit	Nautica
13	WorldView-2 satellite image close to Abu Dhabi islands	DigitalGlobe
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ENTITY PROFILES

Environment Agency-Abu Dhabi (EAD)
is responsible for the protection and management of biodiversity in the Emirate of Abu Dhabi. Founded in 1996, EAD provides direction for government, business and the community in building environmental considerations regarding the way society plans and lives without compromising Abu Dhabi's rapid urban development.

Proteus
is based in United Arab Emirates and specialises in delivering derived data products from Worldview 2 satellite imagery to customers around the world. The company formed in 2011 and has a team with many years' experience in aerial survey, remote sensing and mapping applications. Proteus has delivered successful projects in over twenty countries in Europe, Middle East, Africa and Caribbean. Proteus is an approved partner with Digital Globe.

DigitalGlobe
is a leading provider of commercial very high resolution satellite imagery and geospatial solutions using the highest resolution multispectral satellite imagery available. DigitalGlobe's customers range from urban planners, to the U.S. federal agencies, including NASA and the United States Department of Defense's National Geospatial-Intelligence Agency (NGA). Google Earth and Google Maps high resolution-imagery is provided by DigitalGlobe.

GMV
is the foremost engineering company specialising in the exploitation of Earth Observation (EO) data. GMV has worked extensively for ESA, EC, Country level Cartography Institutes and other clients on the development of EO based products and services and has detailed knowledge of exploiting space technologies.

EOMap GmbH & Co. KG
is located in Seefeld, near Munich, Germany. EOMAP creates solution from Earth Observation data, and were responsible for the marine habitat mapping element of the project. EOMAP's interdisciplinary team consists of highly specialised individuals with professional experience in software development, physically-based remote sensing product generation, cartography, interdisciplinary research, consultancy, and project management.

Nautica Environmental Associates (NEA)
is a company which grew, first and foremost, out of a close working relationship between independent field scientists who, since the early 1990's, had been conducting environmental studies in the United Arab Emirates. Working mainly for the civil and oil/gas sectors and providing a range of disciplines (notably marine biology, terrestrial ecology, ornithology and geomorphology). The company was formally established in 2005.