BIODIVERSITY INTEGRATION IN COASTAL URBAN PLANNING OF ABU DHABI: A CASE STUDY OF SOUTH MUSSAFAH

Jamil Osama
College of Art, Architecture and Design (CAAD), American University of Sharjah (AUS)
osajam123[at]gmail.com

Abstract

Biodiversity integration in contemporary coastal cities is a growing global concern for urban planners today. Coastal cities can host a high richness of urban biodiversity which can assist in providing cultural and environmental ecosystem services. That said, there is limited inclusion of biodiversity in most planning instruments, as they are designed based on public health, safety, and economic growth. In this light, the research examines what components of biodiversity can be sustainably integrated into neighbourhood master plans, urban policies, design strategies, and land-use zoning within the context of Abu Dhabi coastline, the United Arab Emirates as a case study. The research objective is to present a review of the current challenges facing biodiversity in the emirate by assessing the present legislations, governmental plans, and policies and then proposing solutions that can be adapted to counteract the erosion of its natural treasures. For this purpose, experts, and professionals working in the field of biodiversity conservation, urban development, and policymaking, were interviewed for primary information. Additional data were collected through ArcGIS tool analysis, published information from governmental and non-governmental sources to cultivate strategic ecological solutions. This includes providing planning recommendations for protecting urban biodiversity based on ecological knowledge while focusing on the inclusion of environmental issues in the urban development planning process.

Keywords. Climate change; Habitat protection; Urban resilience; Sustainable development; Coastal cities.

1. INTRODUCTION

Biodiversity, a complex network of ecosystems, is a comprehensive term defining the extent of nature's variety or variations within an ecological system. It forms a complex web of life upon which the existence of all living organisms depends [1]. The biodiversity we see in cities today is the result of years of evolution, shaped by environmental processes and majorly by the influence of mankind [2]. As the human population increased over time, devastating impacts started to appear on the existing natural environment and the life that persists in it. One of these disturbing impacts is what we call today "Climate Change" (CC). Ecosystems and biodiversity are intrinsically dependent on climate. [3]. One of the major climatic zones where such a phenomenon can be witnessed is the Arabian Peninsula, particularly the coastal regions of the Arabian Gulf. Due to its harsh weather conditions and rapid urban densification, biodiversity is more vulnerable than ever to climate change in this region. According to studies, the coastline biodiversity is expected to face critical environmental challenges such as rising sea levels, habitat loss, rising temperatures, and extreme weather events soon. Unplanned urban sprawl and population growth of the many littoral cities around this region are accelerating these challenges [3, 4]. Today, countries around the world including United Arab Emirates (UAE), are now focusing on biodiversity enhancement and conservation in urban areas to cope with many environmental impacts [5]. Despite being regarded as a vast desertic and unfertile area, the UAE hosts a unique and remarkably adapted fauna and flora. That said, biodiversity is currently facing major man-made and environmental threats including coastal development sprawl, exploitation of natural resources linked with the tremendous population increase and lifestyle changes. The challenge arises with acknowledging these issues and sustainably planning the existing natural environment. These issues are investigated within the framework of a study area in the South Mussafah region next to *Bul Syayeef* Marine Protected Area along the coast of Abu Dhabi [Image 1]. The primary question animating this research is, what is the role of biodiversity in making UAE's coastal cities resilient to rising climate change impacts? The site under research has relatively rich biological diversity that includes a range of ecosystems, many species characterized by their unique adaptations to the harsh coastal climatic conditions. Therefore, the study also focuses on understanding the complexities of emirate's local natural environment and comprehending biodiversity integration practices that are suitable for the specific context.

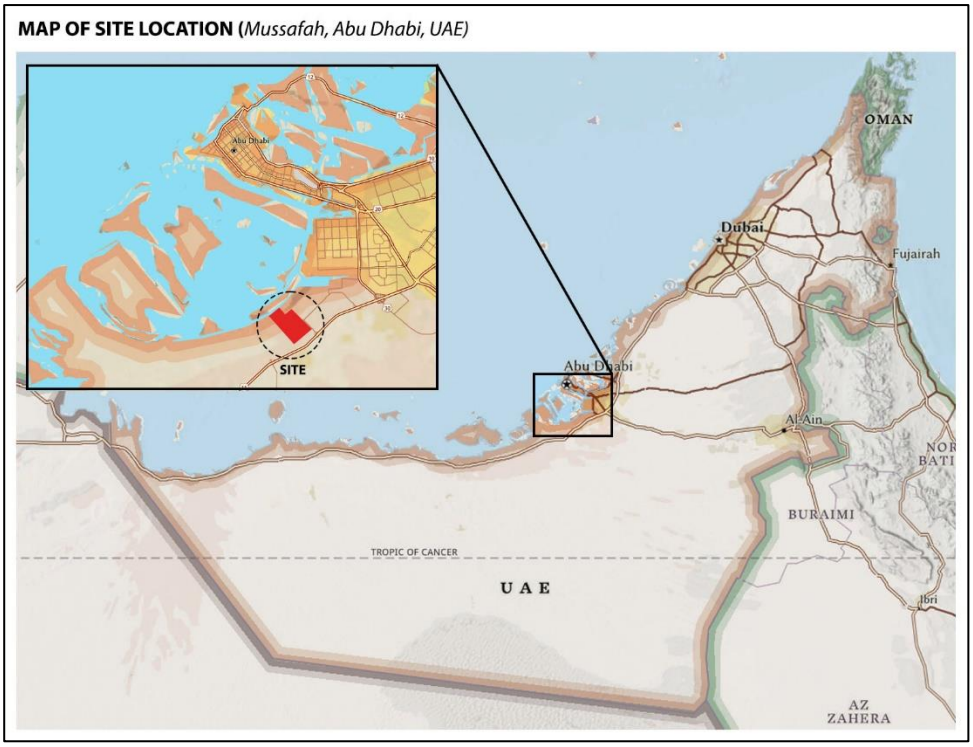

Image 1. Geographic Map of United Arab Emirates showing the site location within Abu Dhabi Emirate. Location demarcated in red box indicates the study area next to *Bul Syayeef Marine* Protected Area
Source. ESRI base maps

2. RESEARCH METHODOLOGY

Three primary methods were used in conducting this research: Semi-structured, open-ended, in-depth, interviews; site visits; and desktop research. Four interviews were organized with professionals in United Arab Emirates' public and private sectors. Environmental Agency- Abu Dhabi (EAD), Department of Municipalities and Transport and Emirates Nature-World Wide Fund (WWF). Site visits to the proposed location and regional wildlife reserves were conducted; regional data collection and analysis were done using Geographic Information Systems (GIS) techniques.

3. BIODIVERSITY CONDITIONS IN ABU DHABI

3.1 ENVIRONMENTAL CHALLENGES

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 [6]. The Marine and Terrestrial Species report 2017 by Environment Agency-Abu

Dhabi (EAD) summarizes the status of the species under different international categories. In addition to the status of the globally threatened species that have been evaluated under the International Union for Conservation of Nature (IUCN) Red List (2014) and the Convention of International Trade in Endangered Species (CITES) [Image 2]. Although less than 2 % of all the species recorded in the emirate are classified as 'threatened' on the IUCN's Red List, a much higher percentage could be considered 'vulnerable' [7].

In the interview with the Marine Program coordinator, Emirates Nature-World Wide Fund (WWF), it was revealed that "an increase in the recent popularity of seafood is decimating global fish stocks, some by more than 50% since 1970". Considering the Arabian Gulf as the world's warmest sea is already a challenging environment for marine life, further temperature rises could have a profound impact. Many terrestrial and marine ecosystems are under various degrees of threat, with several different habitat types considered highly vulnerable because of a significant transformation from their original extent [8]. Areas identified as threatened include coastal plains, sand sheets, dunes, and coastal sabkhas [6]. In the marine realm, corals, seagrass, mangroves, and saltmarshes are highly threatened.

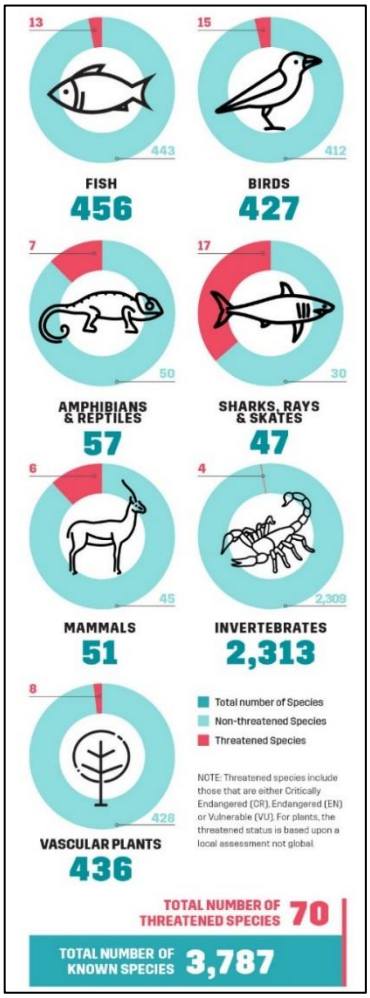

Image 2. Total known and threatened Marine and Terrestrial species in Abu Dhabi Emirate. United Arab Emirates (UAE) is home to important species of invertebrates, plants, mammals, reptiles, and birds, both in the terrestrial as well as marine realms. To date, 3,787 species of plants, invertebrates, higher vertebrates, and fish have been documented in the emirate.
Source. Environmental Agency (EAD, 2017).

3.2 MARINE AND TERRESTRIAL PROTECTED AREAS

Establishing a representative and well-managed network of marine and terrestrial protected areas (MPAs, TPAs) is one of the strongest and most effective conservation measures taken by the local government of Abu Dhabi to protect biodiversity from various threats [6]. Emirates Nature-WWF and the Emirates Environmental Group have been quite successful in elevating concern about the anthropogenic impacts on

the local flora and fauna. The local government and the Environment Agency- Abu Dhabi have managed to conserve various wetlands and terrestrial wildlife habitats in and around urban centres. The emirate features a network of 19 protected areas (comprising six marine and 13 terrestrial) which contribute to achieving 2030 targets for terrestrial and marine protected areas [8]. These areas support some of the best and most critical terrestrial and marine habitats, as well as significant species populations [Image 3]. Proposing any urban development project near protected areas requires a highly sensitive approach towards the habitats. According to the Acting Director of Terrestrial Division, Environment Agency (EAD), there should not be any added environmental or anthropogenic stress on the wildlife, and the public residing in the vicinity must be aware of the consequences of their life choices on the nearby habitats. In 2016, 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 [9].

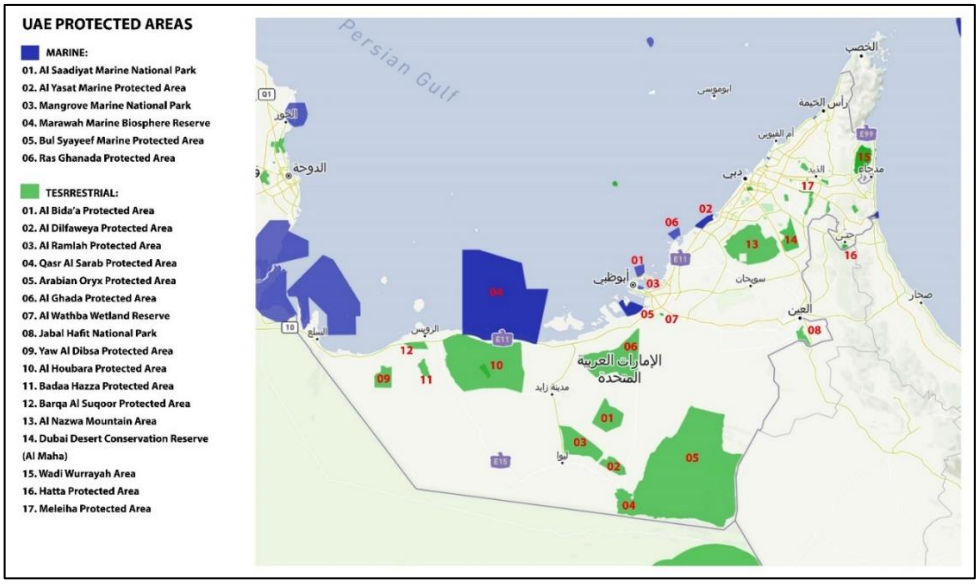

Image 3. Map of Marine and terrestrial protected areas in UAE
Source. ArcGIS data, Ministry of Climate Change and Environment, Dubai

3.3 LOCAL ENVIRONMENTAL LEGISLATIONS

Along with naturally preserved and protected habitats, the government of Abu Dhabi has also been regulating the areas and raising awareness through public policies and regulations. According to Sustainability Health Report 2019, the government has mandated to protect the emirate's key species and habitats through wide-reaching monitoring and conservation programs and effective policymaking [10]. Getting the

permit from the government for coastal constructions especially near marine protected areas (MPAs) is incredibly difficult unless and until the proposal either corresponds or adds to the natural biodiversity of the protected areas. There are only certain land-uses or urban programs which are allowed within the perimeters of MPAs, such as for eco-tourism [7]. According to the Unit Head of Policy and Regulation department, Environment Agency-Abu Dhabi (EAD), the local government holds full rights to approve or disapprove a coastal development proposal. Once the land is allocated, the investors, planners must apply for a construction and development permit, and they must conduct an Environmental Impact Assessment (EIA) study. EAD reviews the application and assessment study to make sure that there is no irreversible impact on the natural environment or existing habitats. Also making sure that the respective measures regarding water quality, air quality, noise, dust, waste are all managed according to UAE and Abu Dhabi by-laws. These assessments are also a part of Abu Dhabi Emirate Protected Area Policy, which sets out Abu Dhabi's vision for designating and establishing protected areas and ensuring that they help achieve positive conservation outcomes. For Example, Federal Law No 24, Articles 04 and 24 issued in 1999 states:

"The project or construction may not launch its activities before the obtainment of the license aforementioned in the previous article including the environmental effect assessment."

"Following a decision issued by the competent authorities, and in coordination with the Agency, works, activities, and acts prohibited in the reserve areas, which may cause the deterioration or damage of the natural environment, harm to the wild or marine life, or affect their aesthetic value, shall be determined." [9]

In previous years, the Ministry of Climate Change and Environment (MOCCAE) and EAD have been successful in developing and implementing strong legislations for urban developments and industries which prohibit, monitor, and assess the urban sprawl. Non-compliance to these legislations results in strict fines or long-term penalties.

3.4 PLAN ABU DHABI 2030

In 2007, The Abu Dhabi Urban Planning Council (ADUPC) designed and implemented a multifaceted initiative to produce an Urban Structure Framework Plan for the evolution of the city of Abu Dhabi. "Plan Abu Dhabi 2030", the Urban Structure Framework Plan, was designed to help Abu Dhabi filter and respond to current and future development needs, establish a planning culture and introduce strong guiding principles for new development. As a part of the Plan, the islands, dunes, sea, coastlines, and native wildlife were given primary importance which blends to create Abu Dhabi's unique natural environment, coexisted with the people living in the city for thousands of years [11]. A 'green gradient' denoting appropriate levels of conservation, restoration, use, and development from the natural core of the park to the urban city core. The Plan further protects the ecological wealth of Abu Dhabi by establishing a protected 'sand belt' and 'desert fingers' to contain urban growth and prohibits urban sprawl [11, 12] [Image 4]. The level of land use allocation, the

Green Gradient, sand belt, and desert fingers provide a framework that can accommodate both the needs of economic development and the needs of ecological preservation. This ecological framework has informed all further aspects of the Urban Structure Framework Plan.

Image 4. Conceptual drawings for Vision 2030 coastal development of Abu Dhabi Emirate
Source. Abu Dhabi Urban Planning Council (ADUPC)

3.5 ENVIRONMENT AGENCY-EAD ANNUAL REPORT 2019

Since 1996, Environment Agency Abu Dhabi (EAD) has been committed to protecting and enhancing air quality, groundwater as well as the biodiversity of desert and marine ecosystems [6]. In 2019, EAD launched a strategic initiative under which the researchers started collaborating with stakeholders of various governmental departments, conducting surveys, and monitoring the wildlife habitats and urban growth patterns. This initiative was essential for a thorough documentation of various animal and bird species and how they have been accommodating to the rapid urbanization. Based on the data collected, the agency then developed digital models and policies to control the urban sprawl and identify the zones which house native species and require protection [10]. In recent times, EAD has taken several astonishing initiatives to assess environmental degradation and the established ground rules to mitigate the impacts of climate change. In Annual Report 2019, Environment Agency published a set of environmental strategies that the

government had either launched or is already involved in [Table 1]. Seeking to raise environmental awareness, facilitate sustainable development, and ensuring that environmental issues remain one of the top priorities of the national agenda [6].

Scale	Strategies
Monitoring the emirate's Terrestrial biodiversity	• Arabian sand cat distribution • The scimitar-horned oryx reintroduction programme • Conserving endangered antelope and gazelle
Assessing the status of Breeding birds	• Breeding bird's status 2019 • Ongoing tracking of migratory birds • Abu Dhabi Birdathon, key figures 2019
Urban biodiversity surveys	• Managing the native plant nursery and seed collection • First ever mapping of Ghaf distribution in the UAE
Establishing and managing Terrestrial protected areas	• International recognition for Al Wathba wetland reserve • Renewal of EAD-dolphin agreement • Expansion of the Zayed protected areas network.
Protecting biodiversity through Policies and regulations	• The sustainable grazing projects. • Developing the first protected areas policy for Abu Dhabi • Conserving the Arabian oryx through national and regional partnerships
Marine & Coastal Habitat Protection	• Developing a sustainable fishery and aquaculture sector • UAE national framework for sustainable fisheries (2019-2030) • Gulf green turtle conservation project results 2018-2019 • Hawksbill turtle nest survey • Mangrove survey results 2019 • Coral monitoring in 2019

Scale	Strategies
Strategic Partnerships	• Single-use plastic policy for Abu Dhabi emirate • Regional technical papers and Workshop on marine issues • Technology innovation pioneers programme – Envirotech • Developing a low-carbon Abu Dhabi government fleet • Charting the course for ocean sustainability in the Indian ocean rim
Assessment, Permitting And inspections	• The environmental Self-reporting programme • The environmental Master Plan. • Holistic compliance environmental Program (HCEP)
Environmental Information and Community engagement	• Green business network (GBN) • Raising awareness on biodiversity and protected areas • Crown prince Majlises • The blue flag program. • Sustainable school's initiative (SSI) • The green youth majlis (gym) • The jane Goodall roots & shoots programme.
Other Strategies & Programs	• Abu Dhabi falcon hospital (ADFH) • Overseeing the sheikh Zayed Falcon release program. • Arabian blue forests Working group. • 360 mangrove national park Educational virtual tour • GEF blue forests Project • 5th annual Abu Dhabi sustainable Business leadership forum 2019

Table 1. List of EAD-Environmental programs and policies
Source. Environmental Agency Annual sustainable report 2019

4. SITE SITUATIONAL ANALYSIS

The United Arab Emirates (UAE) has a rich history of biological diversity that includes a range of ecosystems, terrestrial and aquatic habitats [8]. Marine and terrestrial wildlife in the country has adapted to harsh environmental conditions, but this adaptation may not be sufficient to withstand increasingly warm temperatures resulting from climate change (CC). The urgency of this issue is supported by the recent WWF Living Planet Report 2018 that shows global populations of fish, birds, mammals, and reptiles declined on average by 60 percent since 1970 [13]. The site under consideration for this research is situated in one of the marine protected areas of Abu Dhabi city. *Bul Syayeef* marine area, located close to Abu Dhabi city is one of the most important areas for birds and marine diversity near the city of Abu Dhabi [Image 5].

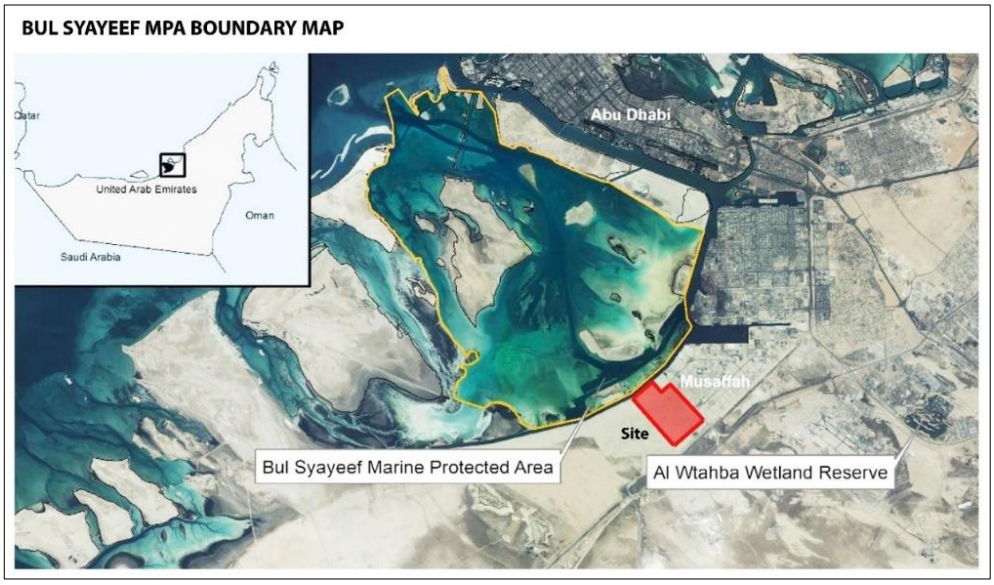

Image 5. Map showing the location of *Bul Syayeef* MPA, Mussafah, Site and other contextual areas under study on the Abu Dhabi coast
Source. Author

The area is of high biological importance due to the presence of large stretches of inter-tidal mudflats, mangroves, and salt marshes, which support rich terrestrial and marine wildlife, and in particular birds. Multiple studies have been conducted by researchers who tracked and surveyed the flamingo and other migratory bird patterns around the coastal areas of Abu Dhabi. The results showed that 7 out of 10 flamingos use the *Bul Syayeef* mangrove is land as a strong feeding and breeding ground. A significant majority of high accuracy GPS locations were clustered around the southern side of the proposed area making it the most important flamingo habitat [14, 15]. These studies show that the site area is a major breeding ground not only for flamingos but many other invertebrates, mammalian and native bird

species which makes the site a potential ground for eco-tourism investments and future urban developments. Unfortunately, the area is also one of the most economically important industrial zones in the country and has huge economic benefits to the national economy. *Bul Syayeef* was designated as a Marine Protected Area in 2007. Before this, the site, and the surrounding areas of the Mussafah region were industrializing rapidly. A transportation water channel was also constructed on the coast to service the Mussafah Industrial Zone and future Industrial City of Abu Dhabi (ICAD) areas. This governmental construction not only harmed the marine ecosystem by damaging the coral reefs but also caused immense pressure on the neighbouring mangrove habitats. Coastal and marine pollution from industrial waste and over-exploitation of living marine resources are contributing to the devastating effects of climate change such as sea-level rise, habitat loss, and wildlife extinction in this biologically diverse territory [8].

4.1 SEA LEVEL RISE (SLR)

The city of Abu Dhabi is located on a low-lying natural island and due to its flat profile, it is most at risk of substantial sea-level rise (SLR) [16]. The annual report published by The Intergovernmental Panel on Climate Change (IPCC) in 2007 depicts multiple SLR forecasts for Abu Dhabi ranging from low rise to extreme scenarios. Based on the analysis conducted for kinematics of ice melt and oceanic heat distribution, the experts have predicted that by 2090-2099, the average water level around the coastal sabkha may increase by 2.0m [17]. In a similar context, an SLR risk assessment study was conducted in 2012 by Earth.Org, where the authors estimated the proportion of urban areas lost to the ocean for different scenarios. In the case of Abu Dhabi, a half-meter rise could submerge 1.46% of the city, quickly jumping up to 9.45% and 15.89% for a 1.5 and 2.0 m rise by 2100. If these statistics are applied to the study area, then it can be predicted that the rising waters will have grave effects on the coastal ecosystems especially the neighbouring mangrove forests [Image 6]. The forecasted impacts of rising waters could have grave effects on the neighbouring ecosystems. Excessive sea rise over a long period can trigger seasonal flooding which may destroy the feeding grounds of migratory birds, cause coastal erosion and nesting sites of turtles and other mammals that could be potentially lost.

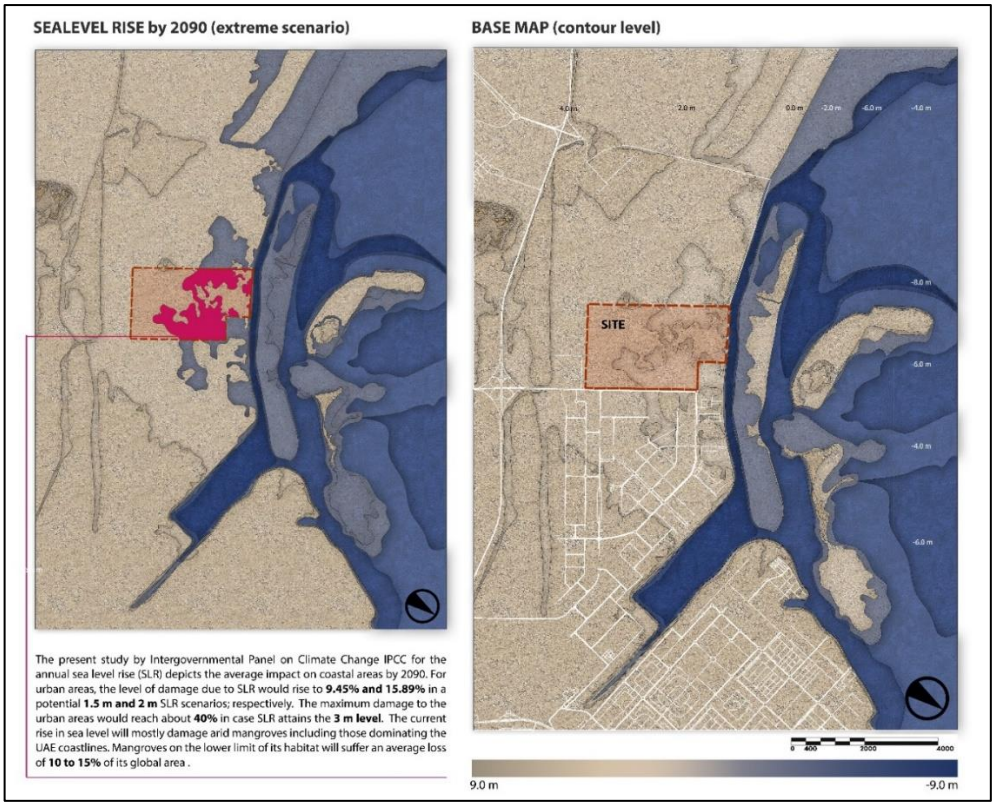

Image 6. Diagram showing sea level rise impacts on the South Mussafah coast in Abu Dhabi (left), Diagram illustrating the built and natural site topography of the South Mussafah coast in Abu Dhabi (right)
Source. Author

4.2 NATURAL HABITATS

The coastal habitats of Abu Dhabi are diverse, consisting of mangrove forests, salt marshes, sandy and rocky beaches, sabkhas and coastal flats with low dunes [12]. Similarly, the coastal vegetation of the region is diverse, and extremely productive, notwithstanding often harsh growing conditions. In case of *Bul Syayeef* MPA, the contextual habitats are diverse including both natural and man-made artificial lands [Image 7]. The Environment Agency Online Portal which categorizes the whole emirate based upon wildlife habitats and natural ecosystems, labels major areas in and round the Mussafah region as "Disturbed Grounds" [6]. This means that the area has already been either drenched or excavated due to industrialization. This makes the coastal area a potential site for upgradation since there are no valuable natural features or major wildlife habitats on the land. As for the marine ecosystems, the diversity is vital to consider since there are major islands, marshy lands, coastal sands, mangroves, cyanobacterial mats, and seagrass present on the southern side which serve as crucial wildlife feeding grounds [14].

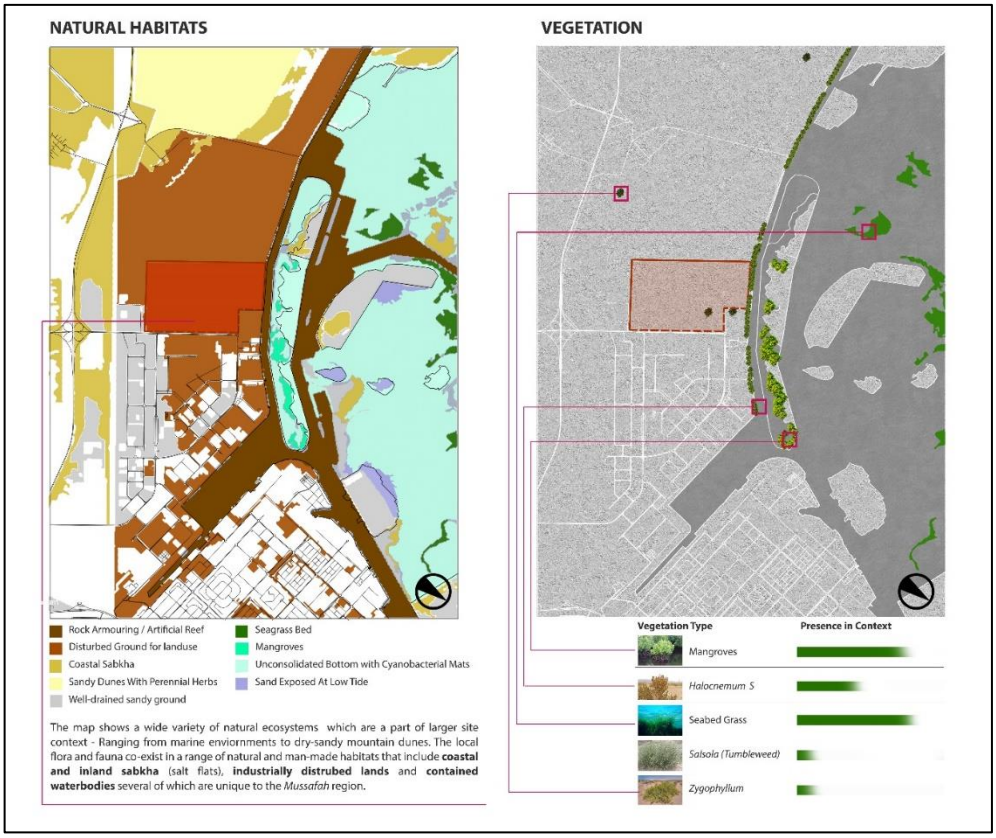

Image 7. Diagram showing natural habitats of South Mussafah coast in Abu Dhabi (left), Diagram showing vegetation levels of South Mussafah coast in Abu Dhabi (right)
Source. Author

Coastal sands are generally favourable for plant growth as well because of the capacity of the coarse sand to store water, often for substantial periods [10]. Once these plant colonies have established themselves along the coast, they serve to stabilize the dunes. These diverse coastal habitats are being affected by climate change, catalysed by coastal development activities [14]. Some foreseeable impacts of man-made constructions include change in annual ranges, migration patterns and possible decline in both marine and sabkha species diversity. Marine ecosystems and fisheries particularly in this region are being threatened by overfishing, but also by other man-made causes.

4.3 LOCAL FLORA AND FAUNA

The presence of perennial surface water across the Mussafah coast towards the mangroves supports a remarkable diversity of species both resident and migratory [18]. The greater flamingo is one of the most noticeable species in the wetlands. It

is the largest species of flamingo, feeding on algae and other shrimps thus cleaning the stranded waters. Due to inaccessibility to the site, it could only be postulated that in addition to birdlife, the area could also be supporting many other local fauna species including the Red Fox, Cape Desert Hare, and numerous small rodents [8]. The number and variety of plant and animal species thriving in such a relatively small area grants *Bul Syayeef* MPA with especially high conservation value. Although long-term trend data from much of the emirate's natural environment is not available, it can only be assumed that many of these species have undergone declines in recent year [Image 8].

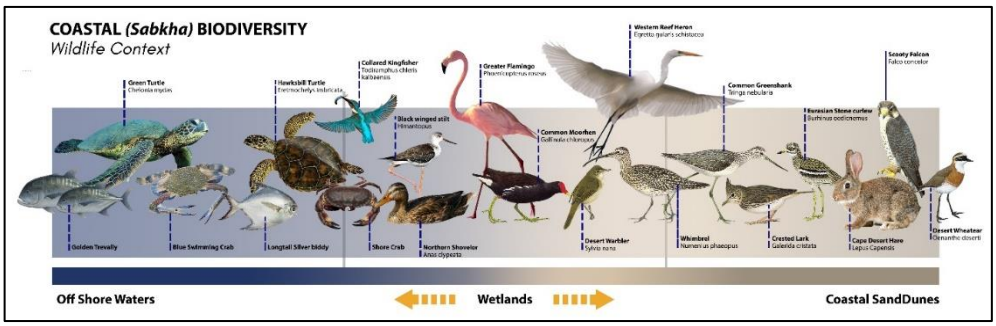

Image 8. Illustration representing a list of fauna species found around Mussafah region, Abu Dhabi
Source. Author

Regards to local flora, the coastal sabkha is not supporting excessive vegetation now since the land is already disturbed. That said, the Abu Dhabi coastline soil can support a diverse range of plants and shrubs including succulents. Mangroves forests, comprising salt-tolerant trees are located on the northern edge across the artificial channel. Mangroves are essential to fish nurseries and contribute to the commercial growth of fisheries in the Emirate [8]. Since mangrove forests are generally inaccessible due to their location in intertidal areas, they are often seriously undervalued as important assets, not only in terms of biodiversity but also as protectors of the coast. With massive root systems, mangrove trees protect coastlines by absorbing and dissipating the force of huge waves, which may cause coastal erosion, property damage and even loss of life. Around the Mussafah region, mangrove forests are under varying degrees of stress, especially close to coastal industrial developments, due to dredging, sedimentation and altered flow methods even though the region comes under the *Bul Syayeef* Marine Protected Area [15].

5. PLANNING RECOMMENDATIONS

Climate change (CC) poses tough environmental challenges for cities. Coastal cities will experience accelerated sea-level rise (SLR), more damaging coastal storms and flooding, and need to profoundly rethink their marine and aquatic edges. A more dynamic shoreline, more flexible and adaptive edges that better function as ecosystems will be required soon [19]. The entire intertidal mudflat, coastal sands,

and salt marsh areas of the Musaffah Channel are highly important for migratory birds as well as many other mammalian species. The new breeding colony, with over 18,000 birds present makes the Mussafah coast and *Bul Syayeef* Marine Protected Area (MPA) a 'Conservation Hotspot', not only for Abu Dhabi Emirate but for the entire Arabian Gulf [15]. Efficient planning and protection of these breeding sites and surrounding areas are not only important but also a national imperative. The successful integration of these areas in future urban developments will highlight the importance of protecting a network of coastal and inland wetland systems and also the urgency with which such areas need to be sustainably protected [20]. As planners, we must look at the cumulative impact of all urban aspects including, road networks, urban form, energy production, and waste disposal for effective biodiversity integration. That said, not all ecological strategies may work in the Abu Dhabi context. Table 2. lists a group of ecological built-environment strategies which can be applied per local climatic conditions, as evaluated through interviewee suggestions and opinions. According to the Unit Head of Policy and Regulation dept. Environment Agency (EAD) is advised to create solutions that focus on preserving the habitat rather than adding to it, minimizing the impacts of construction, and focusing on urban design principles to maximize wildlife-human interaction. Instead of replicating the international solutions as is, focus on local resources and weather conditions. Utilize the various ecological design strategies such as wetlands, local flora, land-use zoning, mangrove additions, and other native conservation techniques which allow wildlife protection and can be integrated into cities for climate change control. Based upon the conducted interviews, and literature review, the following section includes recommended ecological strategies, incentives, and regulations, proposed for the sustainable biodiversity inclusion in future urban planning of study area.

SCALE	ECO-DISTRICT DESIGN STRATEGIES (for biodiversity integration)	ABU DHABI COASTAL FEASIBILITY OPINIONS												COMMENTS
		PUBLIC SECTOR									PRIVATE SECTOR			
		Acting Director, Terrestrial Division- EAD			Unit Head, Policy & Regulations Terrestrial & Marine Biodiversity- EAD			Acting Head, Planning & Infrastructure Sector- Department of Municipalities & Transport, Abu Dhabi			Marine Programme Coordinator, Emirates Nature - WWF			
		A	D	N. A	A	D	N. A	A	D	N. A	A	D	N. A	
Building	Green rooftops		✓		✓			✓			✓			Re-use wastewater for greening
	Sky gardens and green atriums		✓		✓					✓		✓		Depends on the location
	Rooftop garden		✓		✓			✓				✓		Consider using less water
	Green walls	✓					✓	✓				✓		The plants might not survive
	Daylit & green interior spaces	✓			✓			✓			✓			
	Biomimicry	✓						✓			✓			
	Roof/Balcony bird houses	✓				✓		✓				✓		Will attract invasive species
	Vertical farming			✓	✓			✓			✓			
	Solar energy production	✓			✓			✓			✓			
	Green building materials	✓			✓			✓					✓	
Block	Green courtyards	✓			✓			✓			✓			Using local plants that do not need much water
	Clustered housing around green areas	✓			✓			✓			✓			
	Native trees in backyards	✓			✓			✓			✓			
	Rainwater collection		✓			✓				✓		✓		Could be done, but rainwater is not reliable here
Street	Green streets	✓			✓			✓			✓			Re-use wastewater for greening
	Sidewalk gardens			✓	✓			✓				✓		
	Urban trees			✓			✓	✓					✓	
	Low-impact development	✓			✓			✓			✓			
	Skinny streets	✓			✓			✓					✓	
	Edible landscaping	✓				✓				✓		✓		Maybe inside homes or villas Can be done in small pocket parks but not in urban streets due to air pollution
	Wildlife Corridors		✓		✓			✓			✓			
	Pedestrianism	✓			✓			✓			✓			
	Eco-vehicles			✓	✓			✓			✓			
	Cycling Tracks	✓			✓			✓			✓			
Neighborhood	Urban permeability	✓					✓	✓			✓			
	Stream restoration		✓			✓				✓		✓		No streams in Abu Dhabi
	Ecology parks	✓			✓			✓			✓			
	Community gardens		✓		✓			✓			✓			
	Neighborhood parks and pocket parks	✓			✓			✓			✓			
	Greening gray fields and brownfields	✓				✓				✓			✓	Depends on the location and historical land uses
	Bioswales			✓		✓		✓					✓	
	Constructed Wetlands	✓				✓				✓		✓		No need to construct wetlands where they do not naturally exist
Community	Urban creeks	✓			✓			✓			✓			Depends on the location, Dubai Creek is an example.
	Urban ecological networks			✓	✓			✓			✓			
	Green schools	✓			✓			✓			✓			Good for raising awareness and education
	City tree canopy		✓			✓		✓					✓	
	Greening utility corridors	✓				✓		✓					✓	
	Natural Wetlands	✓			✓			✓			✓			Only where there is existing wildlife or natural habitat
	River systems and floodplains		✓			✓		✓			✓			
	Wastewater recycling	✓			✓			✓			✓			Highly recommended
	Urban orchard	✓			✓			✓			✓			Re-use water and organic home waste as fertilizer
Region	Riparian systems (Lakes etc.)	✓				✓				✓		✓		
	Mixed-land uses	✓			✓			✓			✓			
	Urban Forest		✓				✓	✓				✓		
	Regional greenspace	✓				✓		✓			✓			Only if water can be used efficiently (TSE water for example)
	Greening major transport corridors			✓	✓			✓			✓			
	River systems and floodplains			✓		✓				✓			✓	No rivers in UAE, flood plains may exist due to climate change impact
	Wildlife reserves	✓			✓			✓			✓			

Table 2. The report summarizes the best urban design and planning solutions that can be implemented in the South Mussafah coastline, Abu Dhabi as proposed by field experts. "A" = "Agree", "D" = "Disagree", "N. A" = "No Action/opinion". Rows marked in red indicate the best possible nature-based solutions for urban biodiversity integration. (Conclusions drawn from the four interviews conducted in public and private sectors)

Source. Author

5.1 LAND-USE ZONING

Urban sprawl has a large and permanent impact on every aspect of the landscape. For this purpose, conservationists, environmentalists, and planners must become involved in the land use planning process. Efficient and regulated land-use planning can determine how urban areas expand, how they affect the surrounding landscape, and the health of our environment, not just at the macro scale but also within smaller neighbourhoods. For this specific project, some important guidelines must be considered when assigning land-uses to specific sections of the site for habitat conservation.

1. Developing an ecological buffer zone between the site shoreline and the dense urban development. This buffer zone should act as a preserved land for wildlife habitation. This implies that primary commercial and industrial land-uses must be kept away from the coast or at the outer edge of the site to have minimum impact on the seashore [Image 9].
2. Within the boundaries of the preserved land or buffer only certain land uses should be allowed for example eco-tourism, which allows the public to interact and understand the importance of these species in the gulf area. This implies that inside the proposed buffer area and neighbouring *Bul Syayeef* MPA boundary line, only specific land-uses can be added, and those too must qualify the Environmental Impact Assessment (EIA).
3. Dense development and unplanned population growth can eliminate wildlife habitats. Therefore, it is essential to protect the coastline from large density influx, keeping the urban landform compact and away from the preserved land on the coast to have minimum impact on the seashore.

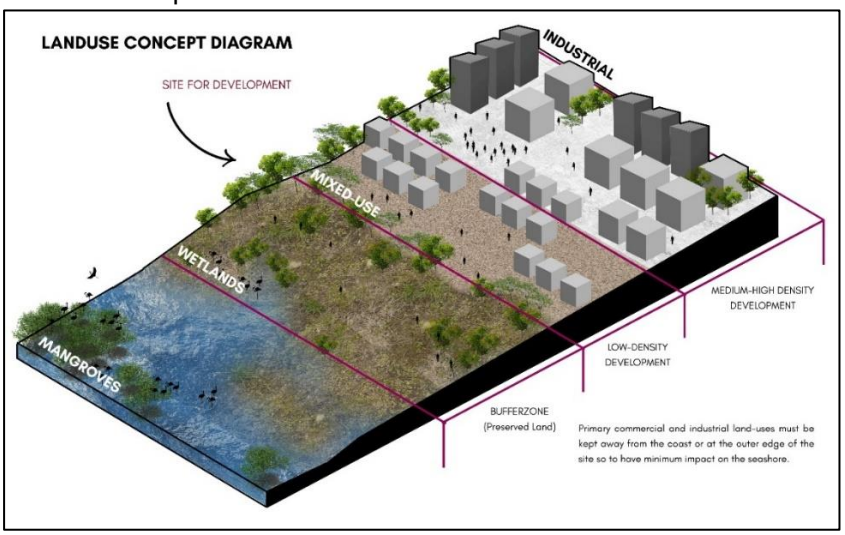

Image 9. Proposed land-use concept diagram showing separate demarcated spaces for successful human-wildlife integration. This implies that dense urban development must be placed away from the coast to reduce the impact on the seashore.
Source. Author

5.2 NATURAL WETLANDS

Abu Dhabi wetlands are a national treasure that provide accommodative breeding and nesting grounds for thousands of bird and animal species. Natural wetlands are one of the finest biodiversity integration solutions which have been confirmed to be successful in the emirate's local context. The benefits are not simply for avid birdwatchers, but the broader community, in terms of leisure opportunities, the promotion of environmental protection and awareness. According to the Acting Head of Planning and Infrastructure sector, Department of Municipalities and Transport-Abu Dhabi, wetlands require specific climatic resources, thorough Environmental impact Assessment (EIA), ground-water level evaluation and extensive geographic study. That said, it is easier for wetlands to be formed naturally around shallow waters and muddy coasts, making them suitable for migratory and local birds. While proposing an urban wetland, the following conditions must be considered.

i. Propose wetland habitats in the sections of the site which are prone to sea-level rise and where the wildlife can exist naturally.

ii. Using dense vegetation or landform to create wetland buffers to screen adjacent human disturbance and serve as habitat corridors through the landscape. Wetland buffers are areas of adjacent, undisturbed vegetation that reduce adverse effects to wetland function from adjacent human development and activities. Most research shows effective buffers are between 20-m to 200-m depending upon the size and wildlife density of the wetland.

iii. Designing wetlands with ecological urban solutions that serve to enhance, preserve, and protect the habitats as natural resources. Urban activities should not damage or disturb the coastal sands, seagrass beds, mudflats, and mangroves. Some compatible solutions include- Provision of observation decks, boardwalks, Deep-sea diving, non-motorized boating, fishing, birdwatching, photography stations, and walking trails [Image 10].

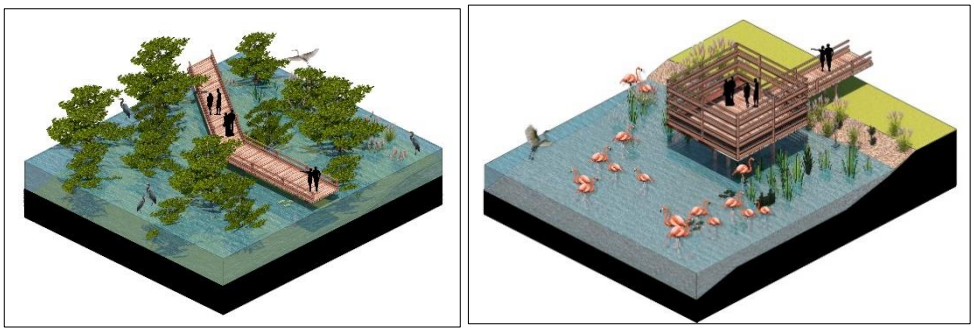

Image 10. Concept diagrams for urban wetland design solutions. (A) shows mangrove island boardwalks (B) shows flamingo observation decks.
Source. Author

5.3 GREEN INFRASTRUCTURE

Green infrastructure networks consist of strategically planned natural and man-made eco-friendly structures, designed to deliver a wide range of ecosystem services. These may include water purification, better air quality, buffering noise pollution, space for recreation, and climate adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities, and enhances biodiversity. Currently, the Abu Dhabi government is emphasizing building sustainable infrastructure and public services for environmental protection. Two important approaches to green infrastructure which can be implemented in the South Mussafah region are:

1. Planning sustainable urban drainage system. This implies that all the domestic solid waste must be separated and recycled as much as possible. Providing recycling trash cans to each residential unit. Organic waste can be separated and used to prepare household compost for community farming. Greywater must collect from the blocks, re-treated, and used for landscaping and irrigation purposes.
2. Designing eco-district traffic networks to minimize automobile usage, encourage pedestrianism, and cut back noise and air pollution which may disturb the nesting birds in the vicinity. Cycling tracks, jogging trails, street furniture, bicycle stations are accommodated within a 200m walking radius. Street width, materials, and textures to help citizens identify street usage [Image 11].

Image 11. Illustration representing green street guidelines. Natural shading, pedestrianism, utility corridors, public transport and use of soft permeable landscaping to enhance the user traffic experience.
Source. Author

5.4 LOCAL FLORA AND FAUNA

Terrestrial surface waters are rare in arid regions, and they represent important biodiversity hotspots of the aquatic and terrestrial flora and fauna, including migratory birds, amphibians, and mammals. The geographic location of the United Arab Emirates attracts migratory European and South Asian birds every year, this makes the country a favourable spot for habitation. Therefore, existing habitats around the site must not be just protected but enhanced by introducing ecological strategies. The standards for designing open public spaces and incorporating local flora and fauna are listed in Abu Dhabi Public Realm Development 2030 Manual (PRDM). It is important to use this document as a base guideline for proposing new interventions.

1. Landscaping in the emirate is a difficult and expensive process, especially for public spaces. It is highly recommended to go for local species that require minimum maintenance and water. Avoid invasive plant species for landscaping as advised by the Acting Director of Terrestrial Division, EAD and if planted intentionally, should be regularly pruned, and maintained.
2. Fauna species that may not cause any harm or damage to the urban environment and human security must be of higher priority. There are wildlife species and animals that can be found lethal to human health, such species must be contained in a specific habitat region through natural barriers.

Kind of plant	Scientific name	Common name
Native species of trees	*Prosopis cineraria*	Ghaf Tree
	Phoenix dactylifera	Date Palm
	Ziziphus spina christi	Sidr Tree
	Acacia nilotica/arabica	Arabian Gum Tree, Babul
Exotic species of trees	*Millingtonia hortensis*	Indian Cork Tree
	Azadirachta indica	Neem Tree
	Delonix regia	Flame Tree
	Conocarpus erectus	Damas Tree, Land Mangrove Tree
	Caesalpinia pulcherrima	Red Bird of Paradise
	Citrus limonum	Lemon Tree
	Cordia sebestena	Geiger Tree
	Plumeria alba	Frangipani
Shrubs	*Tecoma stans*	Yellow Trumpet Bush, Yellow Bells, Ginger Thomas
	Bougainvillea glabra	Paper Flower, Lesser Bougainvillea
	Nerium oleander	Oleander
	Crinum asiaticum	Poison Bulb
	Canna indica	Canna
Other plants	*Catharantus roseus*	Rosy Periwinkle
	Targetes sp.	Marigold
	Zinnia elegans	Zinnia
	Petunia x hybridas	Petunia
Ground cover	*Rhoeo discolour/Rhoeo spathacea*	Boat Lily
	Sesuvium portulacastrum	Sea Purslane
	Portulacarium afra	Dwarf Jade Plant
	Portulaca grandiflora	Moss Rose
Grasses	*Paspalum spp.*	Biscuit Grass
	Pennisetum setacean rubrum	Purple Fountain Grass

Table 3. Local landscaping flora list as indicated by Abu Dhabi emirate habitat classification and protection.
Source. Abu Dhabi Public Realm Development 2030 Manual (PRDM)

6. CONCLUSIONS

As planners, experts, and practitioners, it has become more important than ever to understand and acknowledge the importance of biodiversity in making our cities resilient, liveable, and habitable for all living species. Planning professionals globally need to utilize the potential of urban biodiversity integration to make coastal and terrestrial cities resilient against climate change (CC), simultaneously providing a homogeneous setting for both humans and wildlife well-being. In the Abu Dhabi emirate, where the level of biological and ecological knowledge of most species and ecosystems remains rudimentary, the concept of biodiversity integration in cities could provide valuable knowledge and significantly contribute to habitat conservation practice. There is already a rapidly growing sense of the importance of environmental issues in the country, with the development of a carbon-free city in Abu Dhabi [21], green building design incentives and modern waste disposal methods. In the light of overseen investigation, it is possible to establish an environmentally sustainable urban ecosystem where humans and wildlife can co-exist under specific conditions. Including biodiversity in contemporary costal urban planning process can not only help in creating a diverse human-nature connection but also provide resilience against climate change impacts if regulated and monitored periodically. There are many environmental and biodiversity challenges remaining as we advance globally with the concept and practice of ecological cities [22]. Many policies and research questions remain unanswered, and as urban planners, there is much research left. The ecological movement is robust and cities around the world including United Arab Emirates, are working hard and creatively to address them. It is to be hoped at the end of this paper that effective ecological mitigation and biodiversity conservation will now become a higher priority in the development of the Emirate.

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