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THE IMPACT OF BIOTIC CHARACTERISTICS OF UAE COASTAL AREA ON MOVEMENTS OF SOCOTRA CORMORANT

Nouf Sameer Abdullah Saeed Al Qadi

United Arab Emirates University

College of Science

Department of Biology

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Nouf Sameer Abdullah Saeed Al Qadi

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Sciences

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Declaration of Original Work

I, Nouf Sameer Abdullah Saeed Alqadi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The Impact of Biotic Characteristics of UAE Coastal Area on Foraging Movements of Socotra Cormorant*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Professor Sabir Bin Muzaffar, in the College of Science at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

Student's Signature: ______________________ Date: 5/1/2020

Advisory Committee

1) Advisor: Sabir Bin Muzaffar

Title: Professor

Department of Biology

College of Science

2) Co-advisor: Tareefa S. AlSumaiti

Title: Assistant Professor

Department of Geography and Urban Sustainability

College of Humanities and Social Sciences

Approval of the Master Thesis

This Master Thesis is approved by the following Examining Committee Members:

1) Advisor (Committee Chair): Sabir Bin Muzaffar
   Title: Professor
   Department of Biology
   College of Science
   Signature ______________ Date 15/1/20

2) Member: Aaron Henderson
   Title: Associate Professor
   Department of Biology
   College of Science
   Signature ______________ Date 15/1/20

3) Member (External Examiner): Dr. Humood Abdulla Nasser
   Title: Associate Professor
   Department of Biology
   Institution: University of Bahrain, Kingdom of Bahrain
   Signature ______________ Date 15/1/20

This Master Thesis is accepted by:

Dean of the College of Science: Professor Ahmed Murad

Signature ______________________ Date 24/12/2019

Dean of the College of Graduate Studies: Professor Ali Al-Marzouqi

Signature Ali Hassan Date 28/1/2020

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Abstract

Monitoring Socotra Cormorant population and conducting research on their breeding biology and feeding habits are considered the top priorities for ensuring the long-term protection of their breeding colonies and feeding grounds. The research conducted by using ArcMap Software (10.5) to map Socotra cormorant migratory movements in the Arabian Gulf Region during the 2013-2014 and 2014-2015 breeding seasons.; and to determine environmental variables that affect migratory movements using a GIS approach, which helps to identify areas of conservation value. The study provided needed information on the current distribution of Socotra Cormorant along with the distribution of marine ecosystems (mangroves and coral reefs), allowing for improved management plans of these important ecological assets. Although there is no direct correlation between the movement of Socotra Cormorant and the distribution of both mangroves and coral reefs in Arabian Gulf Region. Nevertheless, the existence of these ecosystems supports the marine life, the stability of coastline.

Keywords: Arabian Gulf, Coral Reefs, Mangroves, Seabird, Socotra Cormorant.

Title and Abstract (in Arabic)

تأثير الخصائص الحيوية للمنطقة الساحلية لدولة الإمارات العربية المتحدة على حركة هجرة غراب البحر السقطري

الملخص

تُعتبر مراقبة واستقصاء غراب البحر السقطرى وإجراء البحوث حول بيولوجيا التكاثر وعادات التغذية من أهم الأولويات لضمان ديمومة اعشاش التكاثر ومناطق التغذية على المدى البعيد. البحث أجري باستخدام برنامج (ArcMap (10.5 وذلك لرسم خرائط توضح حركة هجرة غراب البحر السقطري في منطقة الخليج العربي خلال موسمي التكاثر 2013-2014 و2014-2015؛ وأيضاً لتحديد المتغيرات البيئية التي تؤثر على حركة الهجرة وذلك باستخدام نظم المعلومات الجغرافية. مما يساعد على تحديد النطاقات الجغرافية ذات القيمة الحيوية العالية وحمايتها. قدمت الدراسة المعلومات المطلوبة حول التوزيع الحالي لغراب البحر السقطرى جنبًا إلى جنب مع توزيع النظم الإيكولوجية البحرية (اشجار القرم والشعاب المرجانية)، مما يسمح بتحسين خطط الإدارة لهذه الأصول البيئية المهمة. على الرغم، من أنه لا يوجد أي ارتباط مباشر بين حركة غراب البحر السقطرى وتوزيع كل من الشعاب المرجانية وأشجار القرم في منطقة الخليج العربي. مع ذلك، فإن وجود هذه النظم الإيكولوجية يدعم الحياة الفطرية البحرية واستقرار الساحل.

مفاهيم البحث الرئيسية: الخليج العربي، الشعاب المرجانية، أشجار القرم، غراب البحر السقطرى.

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Dedication

To my beloved parents, family and friends

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List of Abbreviations

EAD	Environmental Agency- Abu Dhabi
GIS	Geographic Information Systems
GPS	Global Positioning System
MOCCAE	Ministry of Climate Change and Environment
PTTs	Platform Transmitter Terminals
SST	Sea Surface Temperature

Chapter 1: Introduction

1.1 Overview

Seabirds are essential components of marine ecosystems (Barrett et al., 2007) that are considered as useful indicators of the marine environment, especially marine biological productivity (Burger & Shaffer, 2008). Their reproductive and foraging behavior reflect oceanographic changes in marine ecosystems (Medeiros Mirra, 2010). Seabird species worldwide are under threat; 17 species are listed as critically endangered, 101 species as globally threatened, and another 35 species as near-threatened (Borrelle & Fletcher, 2017). Globally they are undergoing continuous decline due to habitat destruction, invasive species, fisheries by catch (Muzaffar et al., 2017c). Over 250 Seabird species nest and roost on tens of thousands of Islands around the world (Everett, 2012). Many seabirds nesting colonies are highly threatened like Heermann's gulls (*Larus heermanni*) (Anderson & Keith, 1980), African penguin (*Spheniscus demersus*), and Crowned cormorant (*P. coronatus*) (David et al., 2003). Also, seabirds population viability will be affected by any changes in sea surface temperature (Crick, 2004). Most studies focused on population level, such as breeding success and population viability, but few studies have directly assessed the relationship between climate and behavioral change in seabirds (Medeiros Mirra, 2010). Conservation of threatened seabird remains a global priority and this could focus on the breeding colony protection, protection of non-breeding individuals along with known foraging areas (Muzaffar et al., 2017a).

1.2 Relevant Literature

1.2.1 Seabirds

Seabirds have a unique physiological and morphological characteristic that help in their adaptation to their environment, as they live their life between the air and on the land and in the water. Also, they show a wide range of adaptation from winter in Antarctica to the sunny days in tropical latitudes (Schreiber & Burger, 2001). Seabirds are defined by Burger and Schreiber as birds that are living in and making their living from the marine environment, which include coastal areas, islands, estuaries, wetlands and oceanic islands. They have the ability to fly and spend from weeks to years at sea.

There are about 328 seabird species in four order, the Spenisciformes, Pelecaniformes, Charadriiformes and Procellariiformes. Seabirds size vary from the storm petrels weigh about 20g to the emperor penguin weighted 30 kg. The main common characteristic of seabirds that they feed in saltwater either offshore or nearshore. The marine environment is heterogeneous which allows for a diversity of habitats to feed from (Schreiber & Burger, 2001).

Seabirds are long lived animals (12-40 years) that begin to breed between 2-22 years depending on the species, but most of them begin at age 12 (Everett, 2012). Most seabirds return to land to breed, once per year or less. About 98% of seabirds breed in colonies during selected months of the year (Hamer et al., 2001). Breeding strategy depends on physical disturbance and nutrient input. If the Island is surrounded by highly productive marine habitat the colony can reach 10 million pairs (Everett, 2012). At the breeding season, birds arrive to the colony site to establish a terrestrial nest with about 93% of seabirds have surface and burrow nests (Everett, 2012). Generally, seabirds have an annual breeding cycle, with small fluctuations. Several factors might affect breeding cycle such as food availability, age, experience, length of day, and temperature (Hamer et al., 2001). The size of the colony depends on prey resource, available habitat and interaction between nesting pairs (Everett, 2012). Seabirds may skip breeding for one year because of unfavorable condition or when they are highly disturbed at the nest sites.

Food availability is one of important factors that influence population dynamics and fecundity (laying egg dates, clutch size, egg size and breeding success) of long-lived organisms such as seabirds (Oro et al., 2004). Seabird food is not uniformly available all the time, and fluctuation of food resources plays a significant role in setting the breeding time in all areas of the world. Seabirds can tolerate any changes in temperature, while they are highly sensitive to change in food availability. They will delay or not initiate nesting until food is available. Seabirds are pelagic, feeding on hundreds to thousands of kilometers across multiple trophic levels (Everett, 2012).

Studies on seabird diets spanning over 20 years in the North Atlantic indicate massive shifts in the diet consistent with major changes in fish stocks, pelagic food webs and oceanic conditions. These seabird species in the North Atlantic feed on warm-water pelagic prey like (Mackerel, Squid, Atlantic saury) as primary diet component, they shift to colder water prey, consisting primarily of capelin. Cold water influenced the delay of capelin migration, maturation, swamping, which led them to be available in the seabird breeding season (Montevecchi & Myers, 1996; Bond et al., 2012). Seabird diets have often provided useful information about fish recruitment that can be incorporated in fisheries management models, the reduction in food availability to seabirds considering climate change or fisheries as major threats to seabird food availability. Monitoring of seabird diets over a series of years can help to determine how diets vary as a function of food fish abundance and may indicate the necessary minimum biomass of food fish required to sustain healthy populations of seabirds in particular ecosystems (Barrett et al., 2007).

Seabirds are found at the higher levels of marine food web, some groups, such as storm petrels, feed on zooplankton; others, like gannets, feed on large pelagic fish, while albatrosses are considered as scavengers (Schreiber & Burger, 2001). Seabirds show various ways to exploit the ocean: gulls and terns are coastal feeding species that feed in areas where prey is close to the surface within sight of land. In comparison penguins and alcids considered as inshore feeding species where they can exploit a wide range of depths and within the range of the continental shelf. Some seabird are pelagic feeders species such as shearwaters and albatrosses travel a vast distance from land to forage. Most seabirds are opportunistic feeders if there is lack of adequate prey. They have several ways from prey acquisition either picking from surface or diving to several meters or plunging below the surface (Shealer, 2002). There are factors affecting the foraging acquisition mode such as wind, water clarity and temperature. Although many seabirds are adapted for foraging in windy conditions, small species tend to avoid windy conditions as it makes them unstable and also effects visibility in the water column that could reduce foraging successes (Shealer, 2002). Any changes in physical conditions could lead to a change is biotic variables that can affect seabirds in different ways. Furthermore, in group foraging individuals rely on social facilitation to locate and catch prey (Schreiber & Burger, 2001). As most seabirds are visual predators, they tend to be active during daytime, such as the diurnal Black-footed Albatrosses (Phoebastria nigripes) (Fernández & Anderson, 2000), some could be nocturnal in their foraging habits depending on availability of the prey, while even others might show both diurnal and nocturnal feeding activity (for example, the Red-footed Boodies, Sula Sula and albatrosses, Diomedea) (Schreiber & Burger, 2001).

Our knowledge of seabird foraging behavior is still limited. Most of the seabird diets were based on breeding colonies when seabird must return periodically to the colony. Ship surveys could help us to have fundamental knowledge about the foraging ecology outside the breeding season, when birds are foraging and staying in offshore pelagic waters (Schreiber & Burger, 2001). Nowadays the technology has evolved and new tools such as satellite imaginary has widened the range of observation of the marine habitat, and satellite telemetry has helped to track individuals during foraging trip, and electronic activity recorders the time budget table, and isotope analysis that has helped to determine trophic level utilization. All these technology helps us to fill the gaps and answer many unanswered questions to raise our understanding of seabird foraging ecology (Schreiber & Burger, 2001).

Marine environment is not uniform, there is patchiness in topography, physical properties (temperature, salinity, and turbidity), biological production and biomass, distributed across wide spatial and temporal scales (Medeiros Mirra, 2010). Seabirds are key indicators of changes in the ocean related to climate change on the response to prey. The effect is not uniform: if the sea surface temperature decreases in Siberia the reproductive success of crested auklet (Aethia cristatella) will increase, because the abundant availability of microzooplankton (Kitaysky & Golubova, 2000). While horned puffins (Fratercula corniculata) increase their reproductive success when the sea surface temperature is high, because this is more favorable to mesoplankton production that are eaten by the fish that are, in turn, eaten by the puffins (Kitaysky & Golubova, 2000). Any changes in sea surface temperature (SST) will affect the seabird community due to the changes in fish stocks that they rely on (Crick, 2004). Elegant terns (Thalasseus elegans) in Mexico and United States, migrate 600 km from the Gulf of California in the Midriff Island Region into Southern California northwest searching for more suitable water, which is considered as a drastic respond to the rapid change in oceanographic conditions indicated by high SST (>1.0°C) and the fish availability (Velarde et al., 2015). The North Atlantic Oscillation influences the dynamics of seabird populations, through variability in their food supply that influences breeding, timing of breeding, reproductive success and adult survival (Medeiros Mirra, 2010). Seabirds take prey from various trophic levels making it difficult to detect the effect of changes in physical and biological processes (Medeiros Mirra, 2010).

1.2.2 Socotra Cormorants

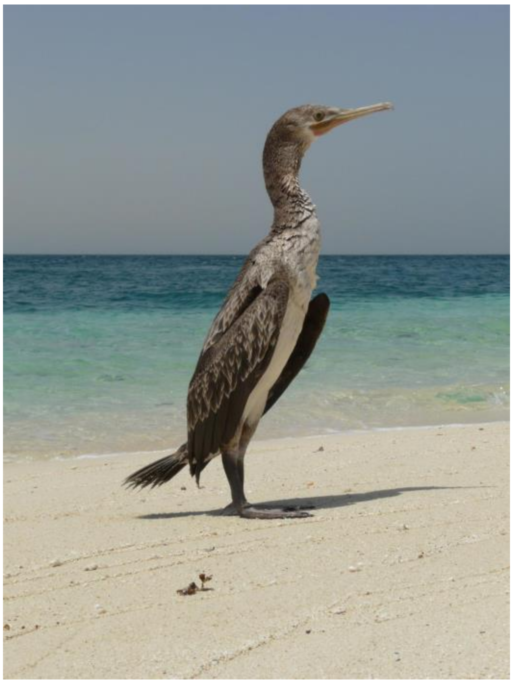

Figure 1: Socotra Cormorant (Phalacrocorax nigrogularis) Shahidbk, IBC1035793 Accessible at hbw.com/ibc/1035793.

Socotra Cormorants (*Phalacrocorax nigrogularis*) (Figure 1) are globally Vulnerable cormorant species, endemic to the Arabian Gulf, Gulf of Oman as well as south in the Gulf of Aden regions (Muzaffar et al., 2013; BirdLife International, 2016).

Their total world population is estimated to be 110,000 pairs (BirdLife International, 2016). There are a few breeding colonies since many have disappeared due to human activities on breeding Islands (Symens et al., 1993) such as costal development, marine pollution (BirdLife International, 2016) and oil exploitation (Jennings, 2010). Unfortunately, there are a total of 14 breeding sites remaining within Arabian Gulf (Muzaffar et al., 2017c; Khan et al., 2018). Socotra Cormorants nest on Islands with sandy or gravel substrate either under trees to avoid predation and shelter from high temperature (Muzaffar, 2012) or nesting on open areas with nest densities of 0.92 m^2 (Muzaffar, 2013), with colony typically having thousands of individuals (Muzaffar et al., 2012). UAE reported 38,000 to 39,000 breeding pairs nesting in 9 islands (Muzaffar et al., 2017c), which is considered to be 35% of global total population (Ksiksi et al., 2015). Abu Dhabi population is on 8-11 sites are estimated to be up to 11,000 breeding pairs (Khan et al., 2018). On Siniya Island, Umm Al Quwain on the other hand, the breeding population has been estimated to be between 26,000 and 41,000 breeding pairs (Muzaffar et al., 2017a). The breeding period is from September to December with incubation period was estimated to be about 24-27 days (Muzaffar et al., 2017b). The clutch size varies from 1-4 egg\nest, hatching success 58.7%, fledge success 65.6% (Muzaffar et al., 2012), Breeding population shows an annual fluctuation due to an environmental condition that is linked with food availability (Muzaffar et al., 2017c), the diet of seabird varies between adult and chicks (Muzaffar et al., 2017b), this might force birds to have a longer foraging trip, which in turn could result in fewer breeding birds in the followed season (Muzaffar et al., 2017a). Socotra Cormorants obtain prey under water by pursuit in shallow water (Cook et al., 2017). Chicks are fed on pelagic fishes approximately 3 times a day (Ksiksi et al., 2015) and the primary food brought to the colony to feed the chicks include flying fish, sardines and anchovies (Muzaffar et al., 2017b). They are highly adaptive to what the fish stock offer, in consequence, there is an inter-colonial variation in the diet, with similarity in the favorable major group (Muzaffar et al., 2017b).

The Socotra cormorant is surface feeding piscivores and has been recorded to feed on Sardines (*Sardinella spp*.), Bigeye scad (*Selar crumenophthalmus*) and Yellowtail scads (*Atule mate*), Silversides (*Atherinomorus lacunosus*), spotted Halfbeaks (*Hemiramphus far*) and Streaked rabbitfishes (*Siganus javus*) in Abu Dhabi (Jennings, 2010). In Siniya Island, Umm Al Quwain, on the other hand, Socotra Cormorants have a diet composed of Sailfin flying fish (99.01%) in early part of breeding season, blue Stripe sardine (60.75%), Pink ear emperor (39.25%), in one year of the study while anchovies were the main component of the diet (100%) species through breeding season in the second year of the study (Muzaffar et al., 2017b). Many cormorant species are opportunistic diet pattern (Muzaffar et al., 2017b). Thus, diet may have significant variation between years depending on environmental conditions that influence the movement and migration patterns of small fish. Cormorants generally are threatened worldwide due to a perceived notion that they deplete fish stocks. This view may not be true for many cormorant species. Socotra Cormorants fall into this category. Fishermen in the UAE consider Socotra Cormorants to be a threat to fish stocks, although the study from Siniya Island, Umm Al Quwain showed that the fish species eaten by the cormorants were not commercially exploited (Muzaffar et al., 2017b). In other words, they were hunting fish that were not important for consumption by humans. Since Socotra cormorants breeding on Siniya Island foraged in areas adjacent to Ras Al Khaimah during the breeding season (Cook et al., 2017). This was consistent with arrival and movement of small fish (anchovies, sardines etc.) in the region and they were restricted to nearshore areas up to 15m in depth (Cook et al., 2017). Once breeding activities were completed, the birds started to migrate towards Abu Dhabi areas (Muzaffar et al., 2017a). Monitoring Socotra Cormorant population and conducting research on their breeding biology and feeding habits are considered the top priorities for ensuring the long-term protection of their breeding colonies and feeding grounds.

1.2.3 Spatial Technology in Studying Seabird

Seabird have been extensively studied worldwide, yet there is still many unanswered questioned about their behavior. It is challenging due to their ability to fly out rang of our observation. It is essential to understand their behavior in order to better plan and create conservation implementation strategies.

Nowadays, with the revolution in the availability of information and technology with respect to Geographic Information Systems (GIS) that have become useful tools to provide us with information on the locomotion, physiology, foraging behavior, migration and demographics of seabirds (Burger & Shaffer, 2008). Data on species and habitat distribution from different dates allow monitoring of location and any changes in targeted area (Salem, 2003). GIS is an essential tool for developing conservation and management strategies for such wide-ranging organisms (Burger & Shaffer, 2008). The data in also used to describe current environmental baseline condition, help to identify species and species habitat, provide a guide in land management and land use, and help to establish and improve biodiversity conservation plans by integrating spatial information to maps and images that can be used for analysis and interpretation and viewing the current status of the target (Salem, 2003). Data can be overlaid to help assess point of overlap and determine areas with ecological suitability (Wani et al., 2016). GIS have the ability to link ecological information with management decisions for ecosystems, while remote sensing provides effective information using satellite images (Mironga, 2004). Remote sensing has been used for environmental assessments. Field survey provide accurate information, whereas remote sensing can provide high quick view to analysis (Wani et al., 2016).

In terms of animal behavior, remote sensing improved our understanding of the movement strategies of species (Wani et al., 2016). To track animal movements and migration routes, seabirds can be equipped with small GPS devices. The power of this tool is the ability to provide data on the patterns of migratory as well as foraging behavior (Wani et al., 2016). GIS and remotes sensing provide a model that enhance the management tool, for example management of aquatic environment. This environment can be quantified, analyzed and changes in spatial and temporal response can be predicted, thus providing managers multiple possible scenarios, which is needed in decision making (Mironga, 2004).

Satellite telemetry is a form of GIS technology that has allowed researchers to gain valuable perception into seabird habitat use, migration routes, and wintering localities. Platform Transmitter Terminals (PTTs) allow the tracking of a variety of bird across wide range from regional to international boundaries. Therefore, it is the only reliable technique for evaluating habitat use, use of existing marine reserves and fisheries management areas (Burger & Shaffer, 2008).

1.3 Study Objectives

Monitoring Socotra Cormorant population and conducting research on their breeding biology and feeding habits are considered the top priorities for ensuring the long-term protection of their breeding colonies and feeding grounds.

The objectives of the study were to

1. Map Socotra Cormorant migratory movements in the Arabian Gulf Region; and
2. Study the effects of some environmental variables on Socotra Cormorant migratory movements using GIS approach.
3. Identify areas of conservation value.

1.4 Research Questions and Hypotheses

The research seeks to answer unanswered question regarding the direction of Socotra Cormorant in the Arabian Gulf and Gulf of Oman using GIS aspect. Also, to know the correlation between the direction of Socotra cormorant in the Arabian Gulf and the existing ecosystem such as Mangroves and Coral reefs. The hypothesis of research stated as:

1. The Marine ecosystem of UAE coastal area effect Socotra Cormorant migration movement in the Arabian Gulf.

1.5 Study Site

The study site is across UAE coastal area along with Arabian Gulf and Gulf of Oman. The United Arab Emirates located on the eastern side of the Arabian Peninsula (Briney, 2018) (51° 35' - 57°10'E, 22°35' - 26°25'N) (The Official Portal of the UAE Government, 2019). It shares a 19-kilometer border with Qatar on the northwest, a 530-kilometer border with Saudi Arabia on the west, south, and southeast, and a 450-kilometer border with Oman on the southeast and northeast. The total area of the UAE is approximately 83,600 square kilometers. UAE stretches for more than 640 kilometers along the southern shore of the Arabian Gulf for 90 kilometers along the

Gulf of Oman. UAE location is strategic, due to vital transit point on Strait of Hormuz for world crude oil (MOFA, 2016).

UAE generally has an arid climate. It is warm and sunny in the winter and during the summer, it is hot and humid (The Official Portal of the UAE Government, 2019), UAE has two distinct seasons, winter and summer. Winter, lasting from December to March, has mean daily temperatures of 15°C. Annual rainfall averages less than 82 mm. A humid southeastern wind, commonly known as the “sharqi,” results in coastal humidity exceeding 85% through most of the summer average temperature reaches (Waibel, 2005).

The Arabian Gulf is a very shallow semi-enclosed gulf with depth less than 100 meters, (Sabbagh-Yazdi et al., 2007), with average depth mean 35 m (Bashitialshaaer et al., 2011), located in the subtropical zone (Naser, 2011). Marine water enters the Gulf through the Strait of Hormuz that connect the Arabian Gulf and Indian Ocean, the water travels in a broadly counter clockwise direction around the basin. As these marine waters travel westwards along the northern shores, the high temperatures, high evaporation and dry winds along with shallowness of the Arabian Gulf leads to the formation of a very highly saline and dense water, the maximum salinities reach 57 g/l along the southern coast (Bashitialshaaer et al., 2011; Bjerkeng & Molvaer, 2000). Salinity varies with temperature and is a critically parameter for marine life (Environmental Atlas of Abu Dhabi Emirate, 2011). The water takes around two and a half year for the completion of water circulation. Higher water temperatures, significantly rising sea levels (Environmental Atlas of Abu Dhabi Emirate, 2011), and rapid coastal development (Alosairi et al., 2011) are serious challenges for the future. Excessive evaporation leads to very high salinity, especially in the southern part of the Gulf (Environmental Atlas of Abu Dhabi Emirate, 2011) the evaporation rate of water is between 144–500 centimeters per year, mean annual evaporation rate is estimated at approximately 1.5 m/yr. The volume is approximately 8,400 km^3 (Bashitialshaaer et al., 2011). The surface temperatures of Arabian Gulf are 15-19°C in winter and 30-32°C in summer (Bjerkeng & Molvaer, 2000).

Arabian Gulf has hydrological features and carries out vital processes that contribute to the overall marine ecosystem. The connection between the Gulf and the Indian Ocean through the Strait of Hormuz limits has influenced the diversity and uniqueness of marine life in the Gulf. Although, the temperature and salinity of the Gulf are harsh, the native species are well adapted, whereas some habitat such as coral reefs are sensitive to the changes in temperature. Winter and spring winds helps the water column mixing which help to dissipate extreme water conditions, these changes drive the abundant cycle of the biomass within Arabian Gulf (Environmental Atlas of Abu Dhabi Emirate, 2011). Arabian gulf hosts some of the most significant marine biodiversity, specially UAE coastal area, including a diverse reef associated fish and large pelagic fish. Coastal habitat varies between coral reefs, lagoons, mangrove, and seagrass beds. Which considered high ecological value, they are shelter for numerous marine species, and prevent coastal erosion (Tourenq & Launay, 2008). Mangrove is a natural ecosystem; it covers about 155.2 km^2 of Abu Dhabi emirate only and their extent of occurrence includes natural as well as planted mangroves. Mangroves are represented by one species, the grey mangrove (Avicennia marina), that can tolerate high salinity (Environment Agency Abu Dhabi, 2014).

1.6 Study Value

This work will provide valuable information on feeding and roosting areas of Socotra Cormorant in the Arabian Gulf. This information is vital importance to conservation planning across UAE coastal area. This also will provide guidance for conservation plan of Socotra Cormorant. Moreover, this work provides essential information on the factors that trigger migration from Sinya Island in Umm Al Quwain, the continuous variation in environmental factors that facilitate migration to Abu Dhabi, and the factors that aid in movement back to the Siniya Island. This migratory behavior, and environmental factors that trigger migration and the areas that are used during migration can be used for future, long-term planning for the protection of this threatened species.

Chapter 2: Mapping Directional Migration in Socotra Cormorants in the Eastern Arabian Gulf

2.1 Introduction

The Socotra Cormorant (Phalacrocorax nigrogularis) is an endemic seabird in the Arabian Gulf and the adjoining Gulf of Oman and the Gulf of Aden waters (Muzaffar, 2014a; BirdLife International, 2016). The global breeding population (110,000 pairs) is located in the Arabian Gulf, and it is considered vulnerable species by IUCN due to a historic decline in population size and extinction of the breeding colonies (BirdLife International, 2016). Socotra Cormorant is known to move widely within the Arabian Gulf and little is known about their foraging ecology and movement patterns across the region (Cook et al., 2017).

The use of satellite transmitters deployed on birds offers a useful method of following the movements of wide-ranging seabirds over the course of their entire annual cycle. The main objective of this chapter is to visualize and demonstrate the movement pattern of the threatened Socotra cormorants and link it later with marine biotic variation in order to explain choice of breeding and non-breeding movements patterns.

The migratory pattern of the Socotra Cormorants is non-dispersive and short-distance with a westward directional migration to islands of western UAE, followed by eastward movement towards the Strait of Hormuz before returning to Siniya Island (Muzaffar et al., 2017a). Thus, conservation efforts are essential to ensure that areas close to the coast are protected, especially when cormorants are foraging.

In the Arabian Gulf, Socotra Cormorants initiate the breeding season from August to January on off-shore islands (Muzaffar et al., 2012), and they forage in shallow coastal waters within 70 km of the colony during this period (Cook et al., 2017). After breeding, Socotra Cormorants move to non-breeding areas in western Abu Dhabi where they use off-shore islands as their main roosting areas (Aspinall, 1995; Muzaffar et al., 2017a). Movement patterns suggests a strong link with oceanographic variables and biotic variable that is linked to fisheries productivity and movements (Muzaffar et al., 2017a). Socotra Cormorants forage widely over the Arabian Gulf during the non-breeding period. Many islands and cliffs are used by Socotra Cormorants for roosting and resting in the post-breeding period (Muzaffar, 2014b; Muzaffar et al., 2017a).

2.2 Methods

Socotra Cormorant study birds were chosen within the study colony on Siniya Island (25°37’N, 55°37’E), breeding adults were captured on their nest by the foot using a noose triggered remotely, then portable transmitter terminals (PTTs) were deployed. The birds were only captured during the late incubation-hatchling phase. No measurements were made on the birds in order to reduce the stress on individual birds from handling.

First breeding season (2013-2014) started in November 2013, 8 birds were equipped with Kiwisat PTTs (Model K3H 174A, Sirtrack), while second breeding season (2014-2015) of 10 birds were equipped with PTTs, using a backpack harness built with 14 mm wide Teflon ribbons. Details are mentioned in Muzaffar et al. (2017a).

Socotra Cormorants were released immediately after attachment of the PTT and were monitored visually after that on the nest site. The PTTs were programmed to record between 00:00 and 05:00 h daily, and the associated signals were received as emails from Argos Satellite directly. In 2013−2014, locations were recorded during the months of November and December 2013, and May and June 2014, from 2331 locations (80 d of recording). There was a gap in satellite signals because of a programming error of the ARGOS system in 2013-2014 year. However, the consolidated data was still useful and was used in the analysis.

In 2014−2015, locations were recorded during the months November 2014 to August 2015 from 16976 locations. Location data with specified levels of accuracy (location classes) were obtained from www.argos-system.org. The data was filtered and low-quality positions (locations classes 0, A, B, or Z) were excluded. About 44.2% of the location in 2013-2014 and 51.6% of locations in 2014−2015 were used in the analysis.

ArcMap Software (10.5) was used to map the accurate GPS positions of Socotra Cormorants in the UAE. The locations of Socotra Cormorants were defined and their movements during (2013-2015) were characterized.

2.3 Results

Total of 19307 GPS locations were received from 18 study birds over the two study periods. The overall movement for each bird were summarized in the figures below, which highlighted the general trend movement for each individual.

About 84 GPS locations were received from bird 1 during November and December 2013. As shown in Figure 2, the movement of bird 1 started from Deira Islands in Dubai (point 1), then the bird went to Siniya Island in Umm Al-Quwain (point 2), after that the bird moved to the World Islands in Dubai (point 3). Point 4 signals indicates that the bird was still located in Dubai. Signals from bird 1 ended while it was in Ghanadah in Abu Dhabi (point 5).

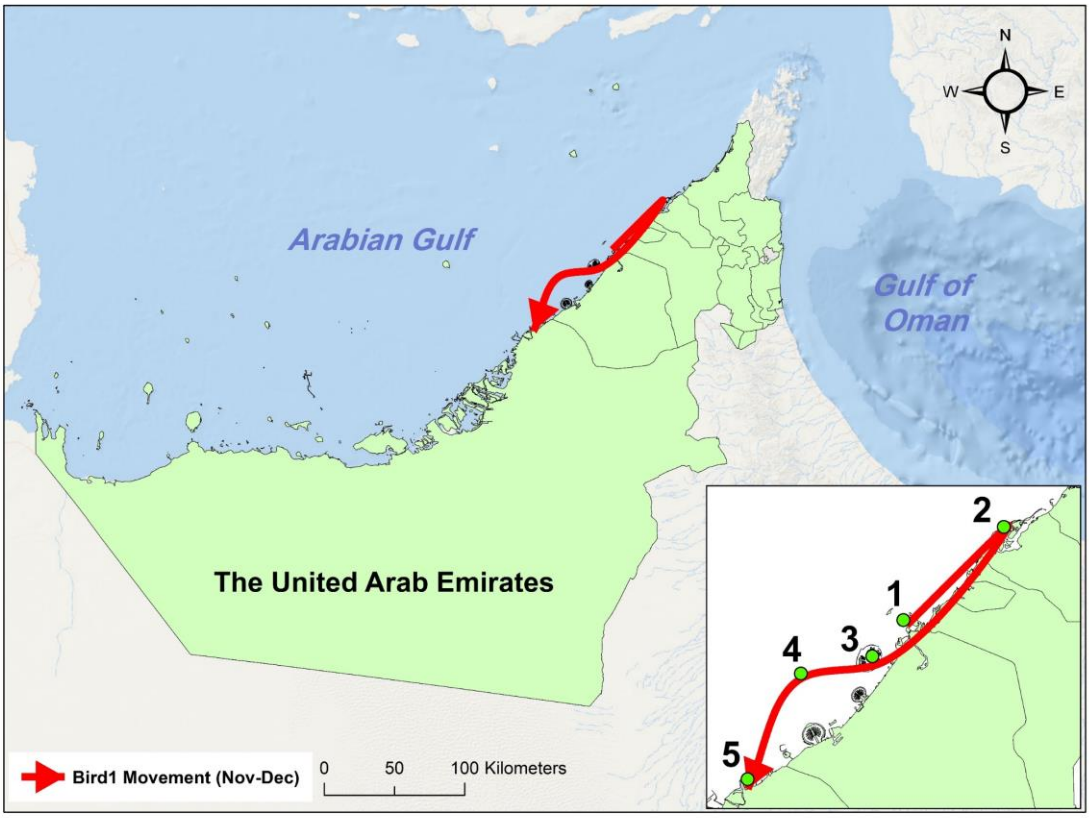

Figure 2: Bird 1 Movement during November and December 2013

Bird 2 moved to the opposite direction toward the northern part of the UAE, starting from Umm Al-Quwain and ending in Ras Al-Khaimah as seen in Figure 3. The signals were received from 18 November 2013 until 9 December 2013, with 72 GPS locations. The bird visited three main sites, first the starting point 1 at Siniya Island in Umm Al-Quwain which is already known that there is a well establish breeding colony in it. Second, point 2 shows that the bird was foraging in Al Hamra Island in Ras Al-Khaimah. Third, point 3 shows that the bird was foraging in Al Rams near to Saraya Island in Ras Al-Khaimah as well.

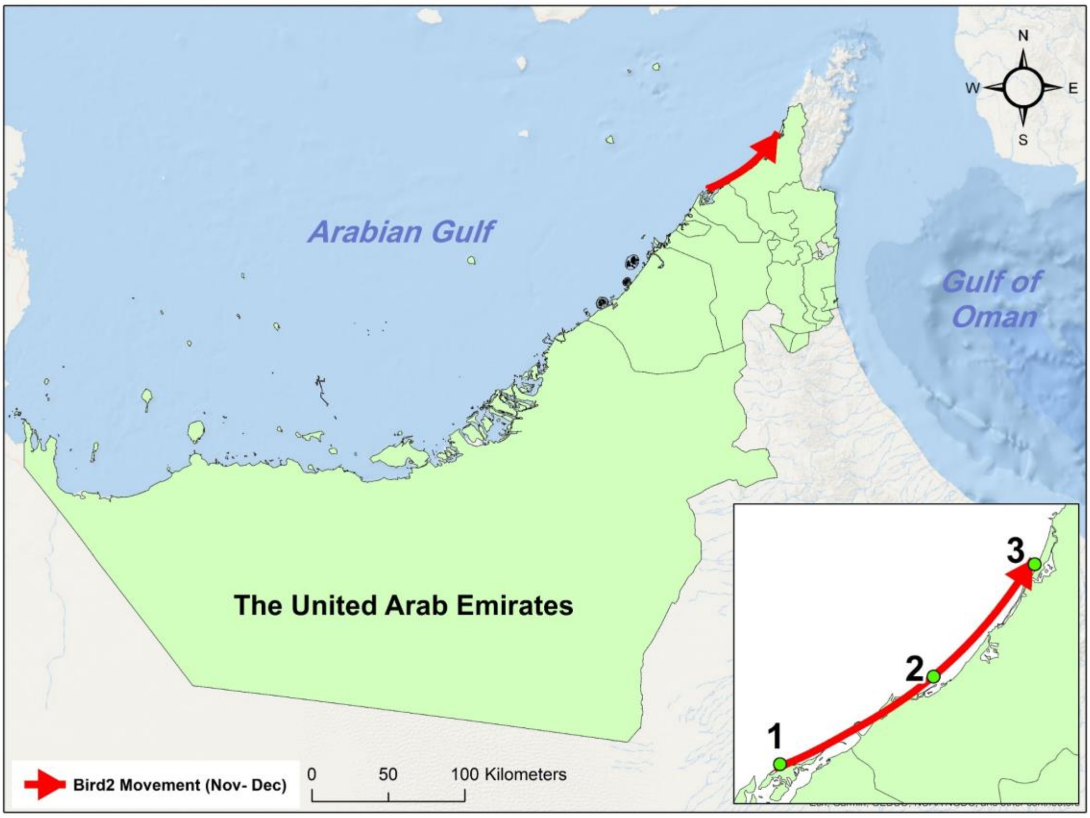

Figure 3: Bird 2 Movement during November and December 2013

Bird 3 showed two foraging trips as seen in Figure 4. The red line shows November and December 2013 foraging trip, while the yellow line shows May 2014 foraging trip, with total 170 GPS locations received. The GPS started receiving signal from 18 November 2014 from Dubai (point 1), about 7 km away from Deira Islands. Then the bird moved to Siniya Island in Umm Al-Quwain and it stayed there for several days as shown in point 2. After that the bird returned to the World Islands in Dubai as shown in point 3, then it continues toward Abu Dhabi. From the end of November to early late December, bird 3 has spotted in different area across Abu Dhabi, point 4 shows that it was in Al Rafiq Island, then the bird moved between Umm Jassar Island and Umm al Kurkum Island (point 5). Finally, the bird ended December trip at Al Dabiya in Abu Dhabi.

Even though May trip was short, starting 1 May 2014 until 8 May 2014 with total 116 GPS locations, most of the signals were received around the World Islands in Dubai (point 7). Then it went far across emirates until it reached Khasab in Oman as shown (point 8). After that, it returned back to the World Islands in Dubai.

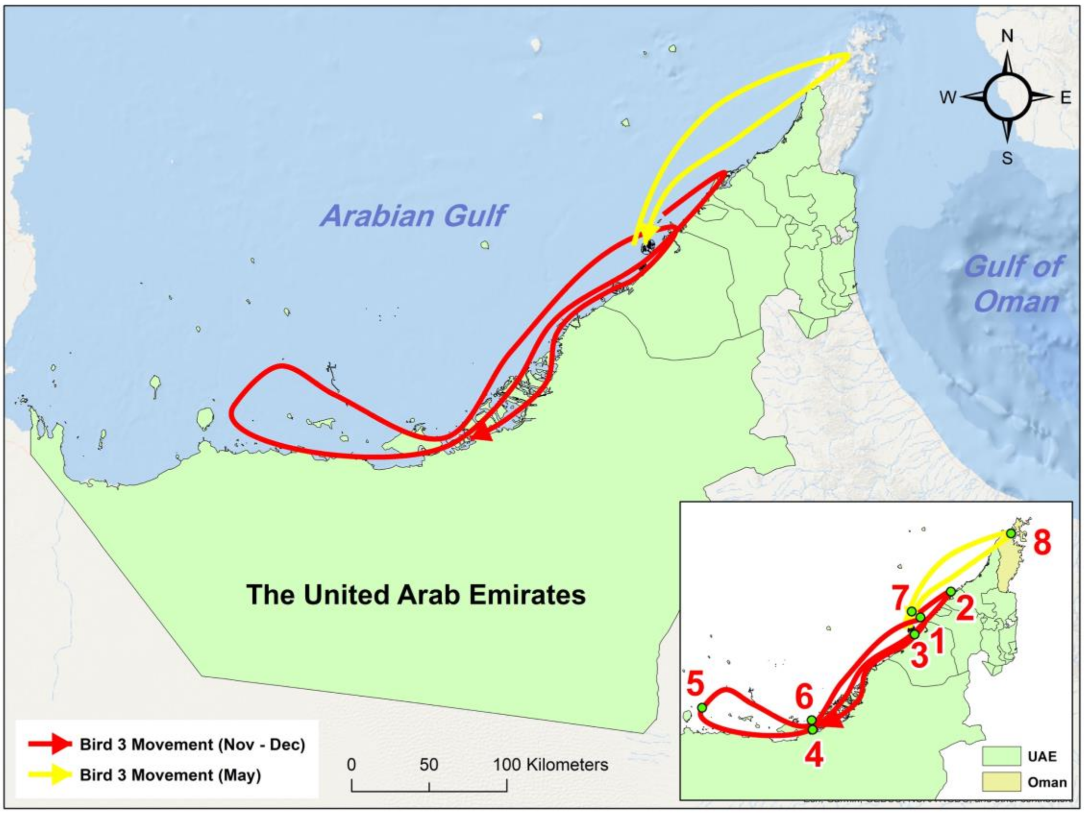

Figure 4: Bird 3 Movement during November & December 2013 - May 2014

Bird 4 started its migration from Siniya Island in Umm Al-Quwain on 18 November 2013. About 97 GPS locations were received from different locations. Figure 5 illustrates the movement into 6 main sites. Point 1 shows the starting point from Siniya Island in Umm Al-Quwain moving to point 2 which is Al Hamriyah in Sharjah. Point 3 shows that the bird went to the World Islands in Dubai. The three final stops 4, 5, and 6 were all located in Abu Dhabi; and they are relatively close to each other. Point 4 shows Al Rafiq Island, while point 5 shows a location in the Arabian

Gulf between 3 main Islands: Halat Al Bahrani, Al Aryam and Abu Al Seyayif. Finally, point 6 shows Abu Al Abyad Island.

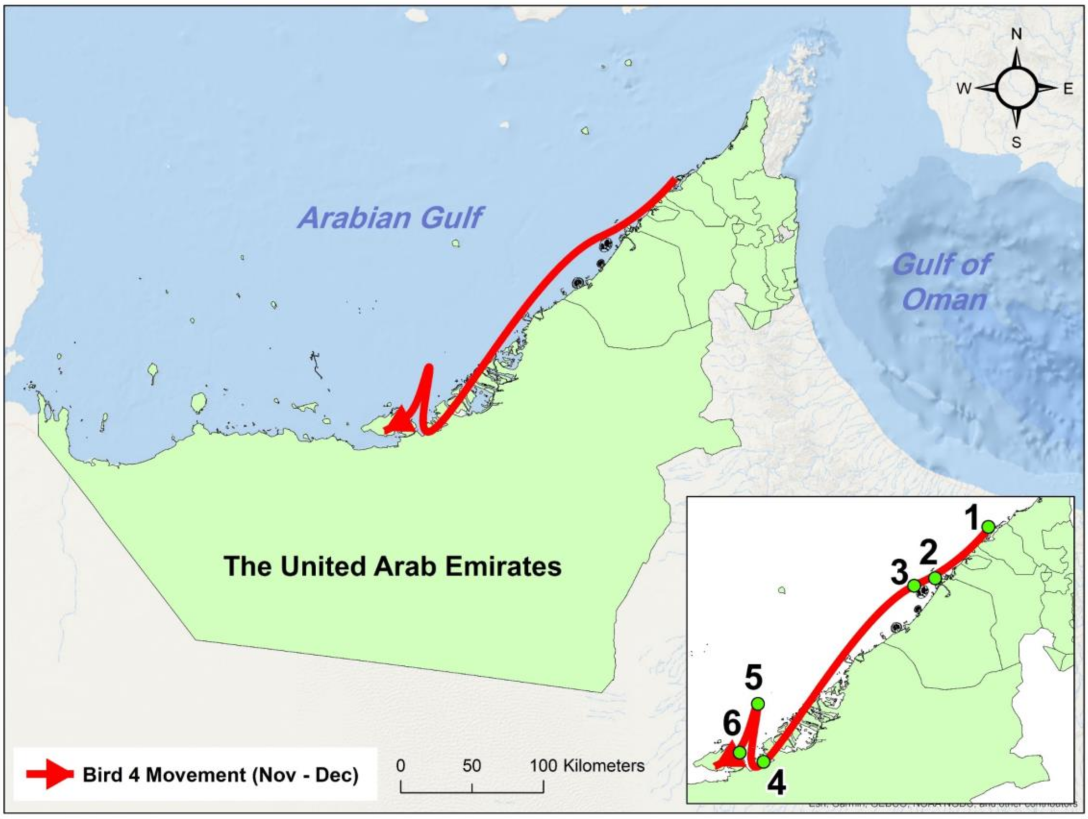

Figure 5: Bird 4 Movement during November and December 2013

For bird 5, the signal points were received starting from November 2013, with a total of 82 GPS locations that shows the bird movement between three Emirates (Figure 6). The movement started from Siniya Island in Umm Al-Quwain toward the World Islands in Dubai in December 2013. However, in middle of December 2014, bird 5 moved to Abu Dhabi near Al Weheil Island (point 3), then near Al Dabiya Island (point 4), and finally near Abu Al Abyad Island (point 5).

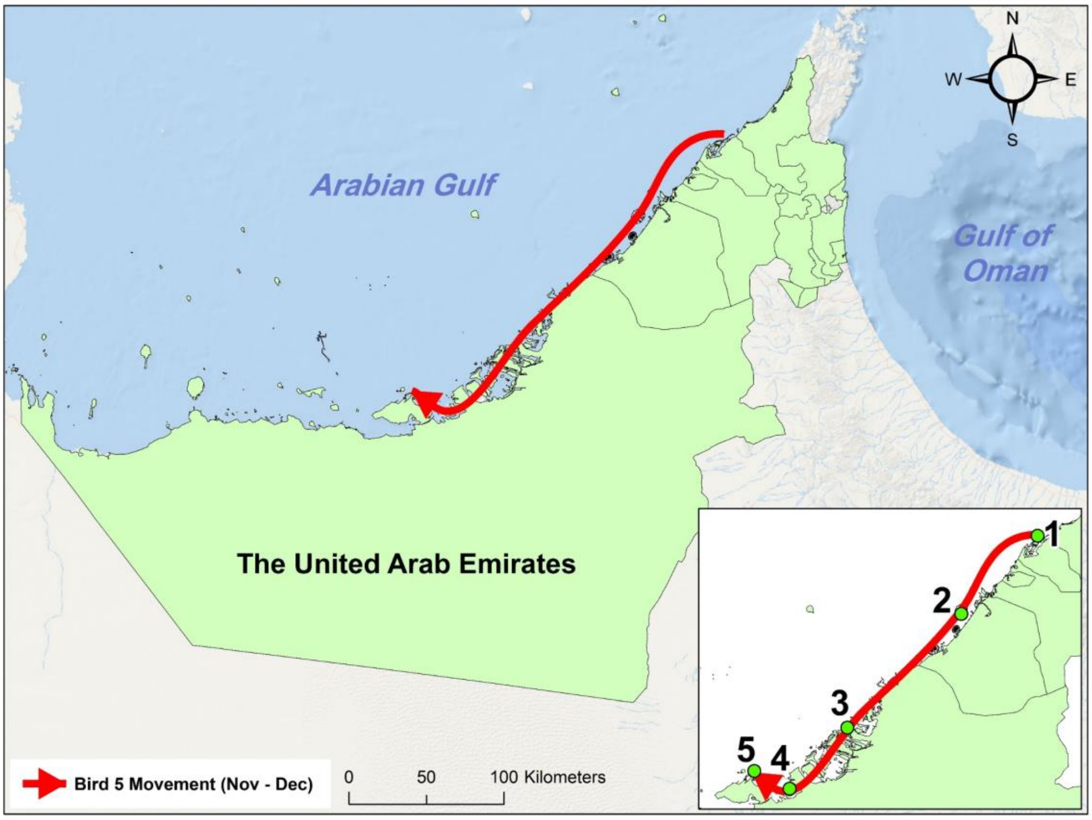

Figure 6: Bird 5 Movement during November and December 2013

Bird 6 started foraging trip as seen in Figure 7 in November 2013, with a total 96 GPS locations. Bird 6 spent November 2013 in Siniya Island in Umm al-Quwain. However, by the beginning of December 2014, it moved toward Abu Dhabi with several stops. Point 3 indicates that the bird is foraging in Deira Islands in Dubai, then moved to around the World Islands in Dubai. From the middle of December 2013, it moved to Abu Dhabi until the end of December 2013. Point 4 shows that the bird is foraging in Bu Niyaydah, Khor Faridah near Ras Ghurab Island. Point 5 shows that the bird is around Al Hidayriyyat in Abu Dhabi. Finally, point 6 shows that it is in Al Dabiya in Abu Dhabi.

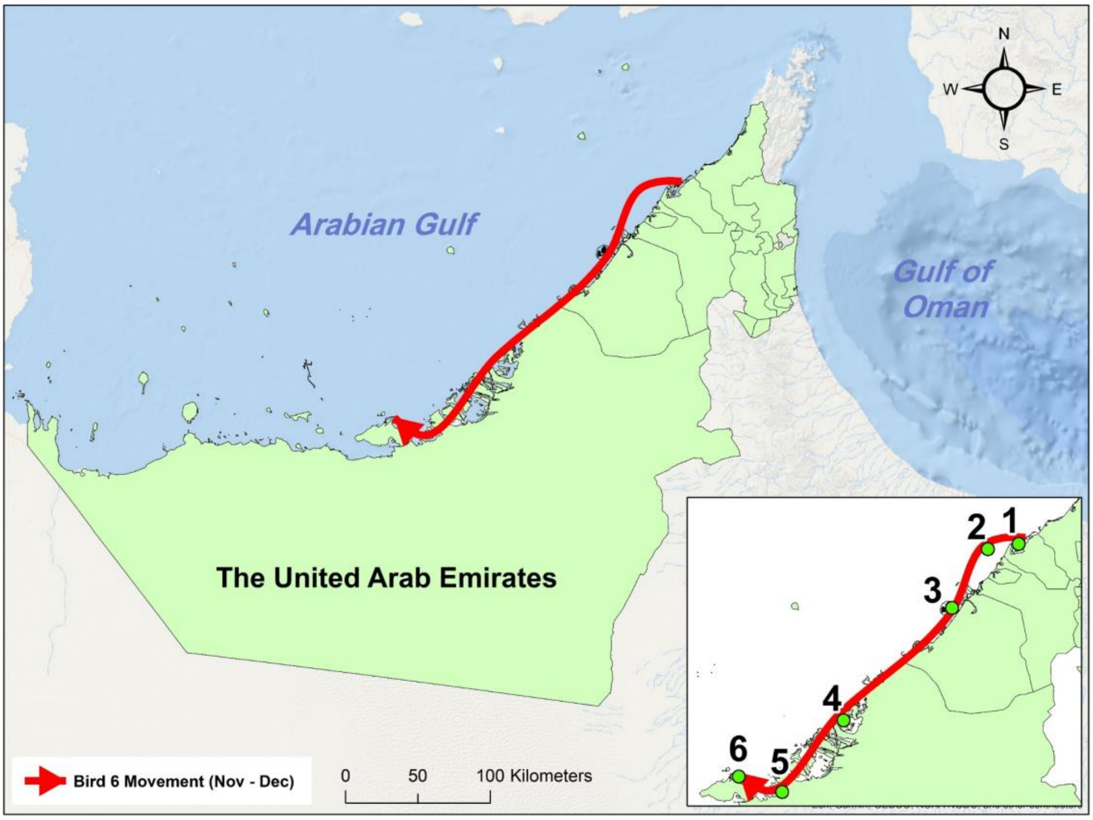

Figure 7: Bird 6 Movement during November and December 2013

Bird 7 have 490 GPS locations covered from November 2013 to December 2013 (red line) and from May 2014 to June 2014 (yellow line). Point 1 in Figure 8 indicates starting point for the bird in 18 November 2013 that was in Siniya Island in Umm al-Quwain. The bird remained there until the end of November 2013, then in December 2013 it moved to Kumzar in Oman (point 2), while point 3 shows that it moved to Limah in Oman until 19 December 2013. However, there is a shortage of data for the rest of December.

The second line tracking started from 8 May 2014 in Palm Jumeirah in Dubai, and later in the late May 2014, it went far to Khasab in Oman. Then it went to Musandam Governorate in Oman. By end of May, it moved back to Ras Al-Khaimah in UAE. In June 2014, it was in Al Rafaah in Umm Al Quawain, then from middle to the end of June, it returned back to Kumzar in Oman.

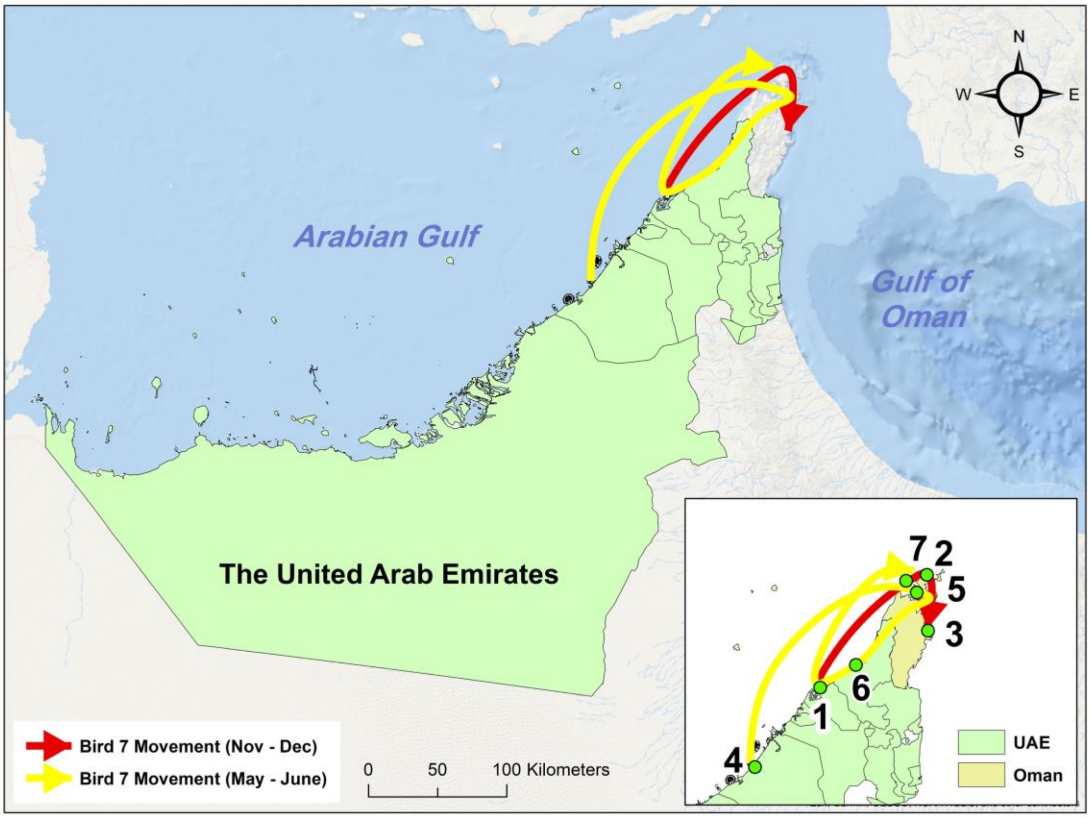

Figure 8: Bird 7 Movement during November / December 2013 – May /June 2014

During November 2013, bird 8 was foraging in Ras al Khaimah and Umm Al Quawain. Then the bird moved all the way to Abu Dhabi during December 2013. As seen in Figure 9, the bird started moving in earlier December 2013 from Siniya Island in Umm Al Quawain towards Ajman in point 3. Then it went to Deir Island and the World Islands in Dubai (point 4). Point 5 shows that the bird was around Al Heel Island in Abu Dhabi. Finally, point 6 shows that the bird is Abu Al Abyad Island in Abu Dhabi.

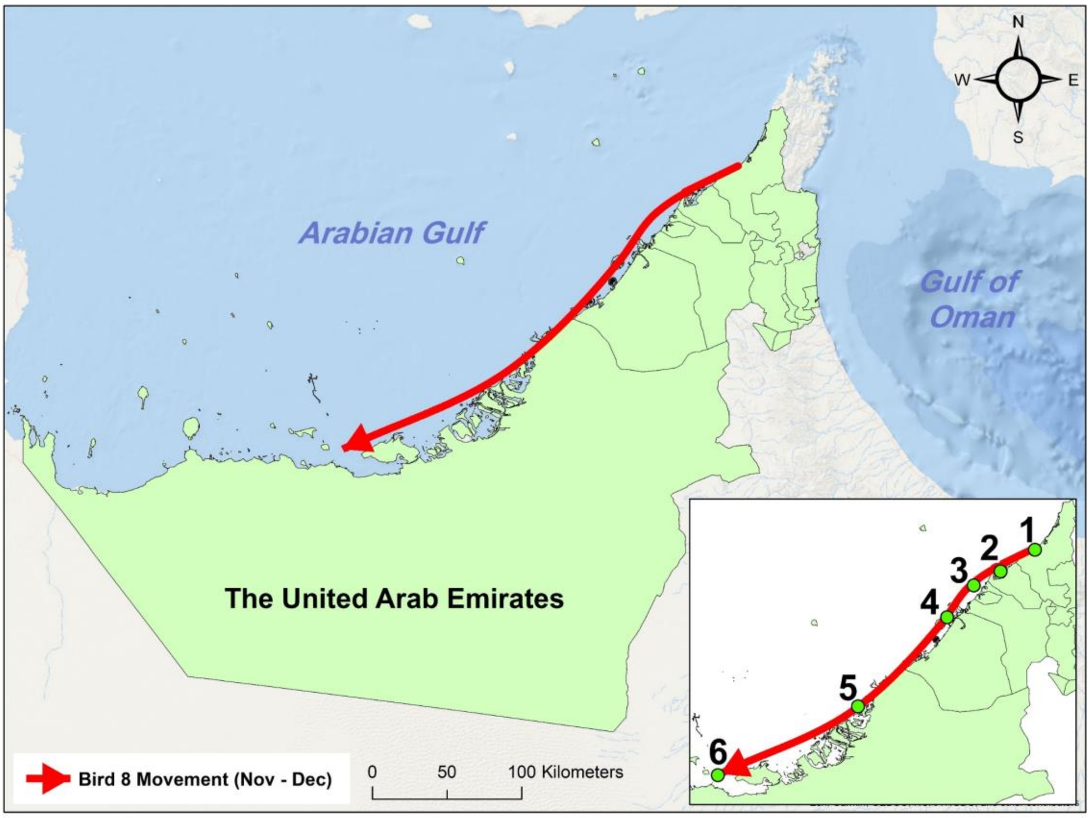

Figure 9: Bird 8 Movement in November and December 2013

About 986 GPS locations were received from November to December 2014 and from January to August 2015. During November 2013, bird 9 went to three emirates: Ras Al-Khaimah, and Umm Al-Quwain and Dubai as shown in Figure 10 (points 1, 2, and 3). By beginning of December, bird 9 moved toward Al Dabiya in Abu Dhabi (point 4). Then it stayed in Sir Bani Yas in Abu Dhabi (point 5) until February 2015. There were few signals between point 4 and point 5 during early January 2015, then the bird moved to Bu Tinah Island until mid of April (point 6). However, by the late of April, it went to Mubarraz Island in Abu Dhabi (point 7), after that it moved to Deira Island in Dubai (point 8). From late of April 2015 until end of July 2015, it was in Musandam Governorate (point 9), finally in the first of August 2015, it was in Tibāt in Oman (point 10).

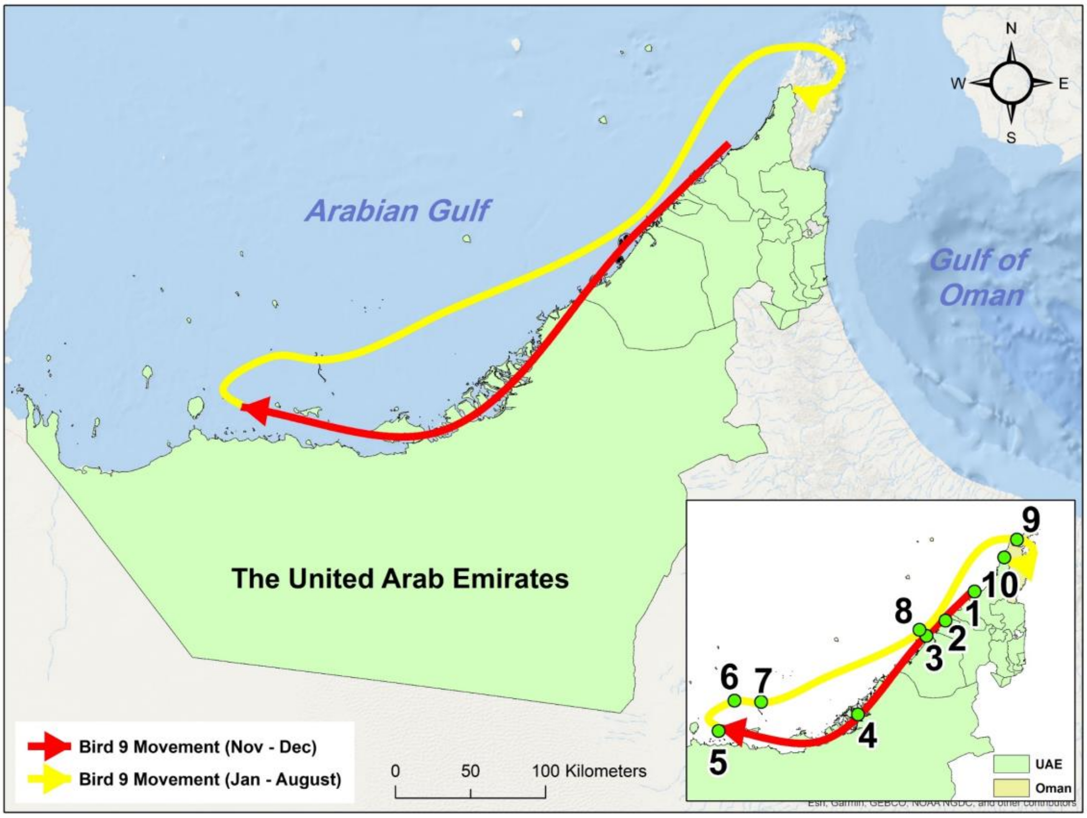

Figure 10: Bird 9 Movement during November - December 2014 and January – August 2015

Figure 11 shows that there are 2 directional paths for bird 10, one in December 2014 (red line) and the other one in January-March 2015 (yellow line). During December 2014, the bird was in Siniya Island in Umm Al-Quwain (point 1). Then the bird went the World Islands in Dubai (point 2). After that, it went to Al Dabiya in Abu Dhabi (point 3). In January 2015, the bird was around Abu Dhabi close to Bu Tinah Island (point 4). However, during late of January 2015 until mid-February 2015, the bird went to Mubarraz Island in Abu Dhabi (point 5). Furthermore, the bird moved to Umm al Kurkum Island (point 6) and to Abu Al Abyad Island in Abu Dhabi (point 7). Finally, the bird went Khor Al Bazim in Abu Dhabi and stayed there till 8 March 2015 (point 8).

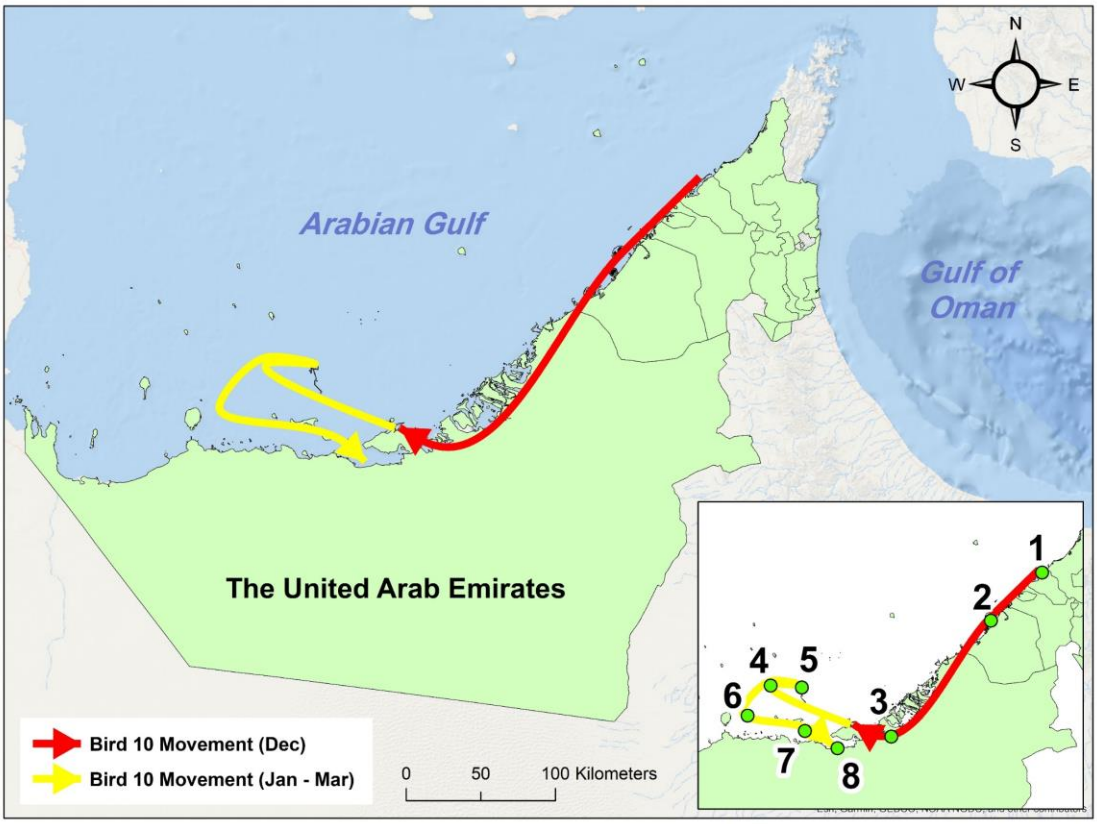

Figure 11: Bird 10 Movement during December 2014 and January - March 2015

About 231 GPS locations were received from November 2014 until January 2015. Figure 12 illustrate the movements of bird 11. Point 1 indicates that the bird was in Siniya Island in Umm Al-Quwain, then it moved in late November to Deira Islands in Dubai. After that, it returned back to Siniya Island during December and stayed there until 18 January.

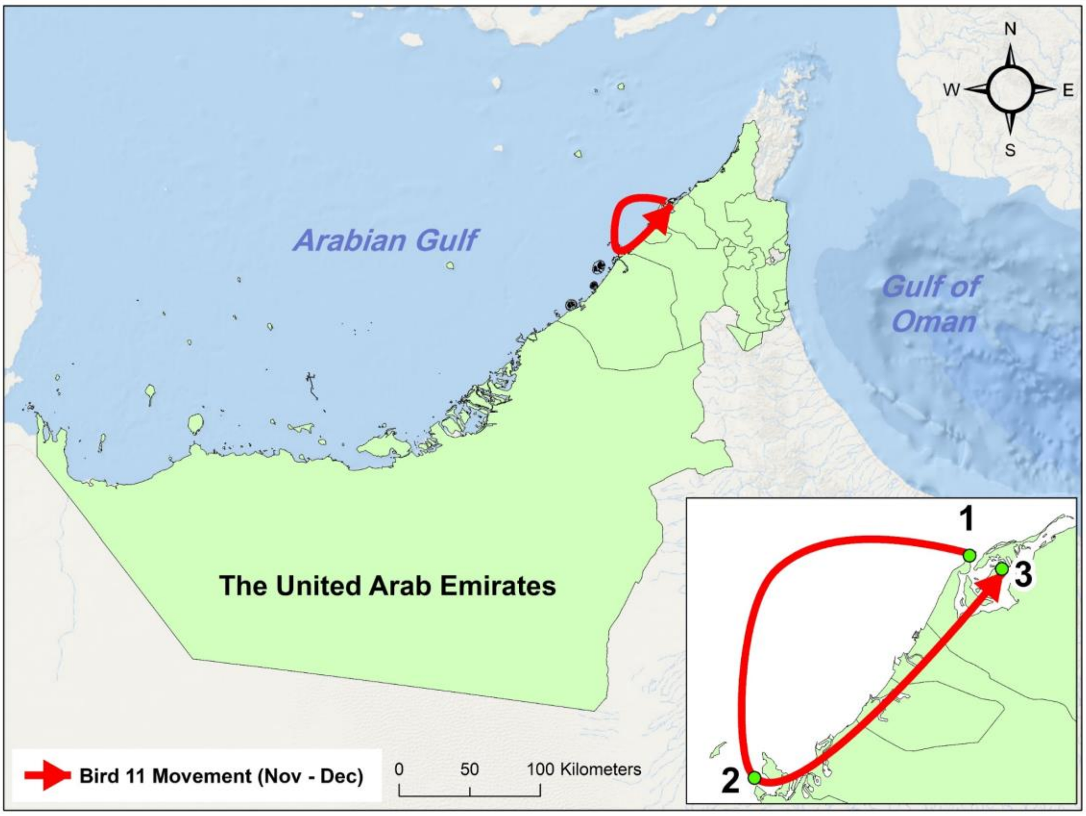

Figure 12: Bird 11 Movement during November - December 2014 and January 2015

Bird 12 started its foraging trip as seen in Figure 13 in November 2014 from Dubai close to the World Islands as shown in point 1, while point 2 indicates that the bird moved to Umm Al-Quwain until the end of November 2014. In December 2014, the bird moved to Abu Dhabi. Point 3 shows that it was foraging in Al Dabiya in Abu Dhabi. From late of December 2014 until mid-April 2015, the bird moved into several locations in Abu Dhabi including Bu Tinah Island (point 4), Umm Jassar (point 5), Al Fiyay Island (point 6), and Al Halah Island (point 7). However, in late of April 2015, the bird moved toward Khasab in Oman until early of June 2015 (point 8). Then the bird went to Ras Al-Khaimah coastal line (point 9). Yet, the bird returned back to the nesting colony in Siniy Island in Umm Al-Quwain (point 10), it went to Deira Island in Dubai (point 11) until the end of June 2015. GPS device also received 5 signal point from Al Rafaah in Umm Al Quawain in 16 July 2015.

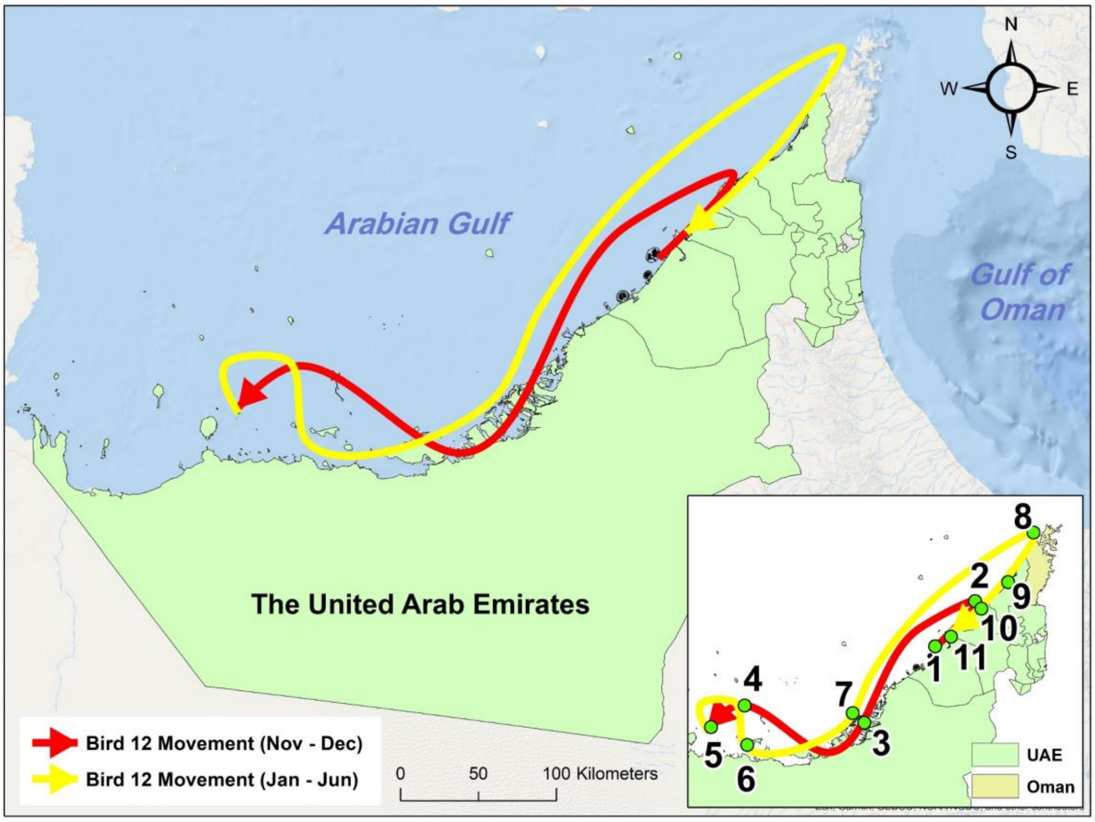

Figure 13: Bird 12 Movement during November - December 2014 and January - June 2015

Figure 14 shows the movement of bird 13 that started in November 2014 in Umm Al-Quwain (point 1), then it moved to Deira Islands (point 2) and the World Islands (point 3) in Dubai. By beginning of December, the bird moved to Abu Dhabi and it was foraging close to Abu Al Abyad Island (point 4) and Al Dabiya (point 5). By mid-December 2014, it went to Al Mirfa (point 6) and Bu Tinah Island (point 7) in Abu Dhbai. However, by mid-March 2015, the bird moved to Baynunah Island (point 8), then it moved to Sir Baniyas Island (point 9) in Abu Dhabi. By late of March 2015, the bird went close to Diynah Island in Abu Dhabi (point 10), then it went close to Doha in Qatar (point 11).

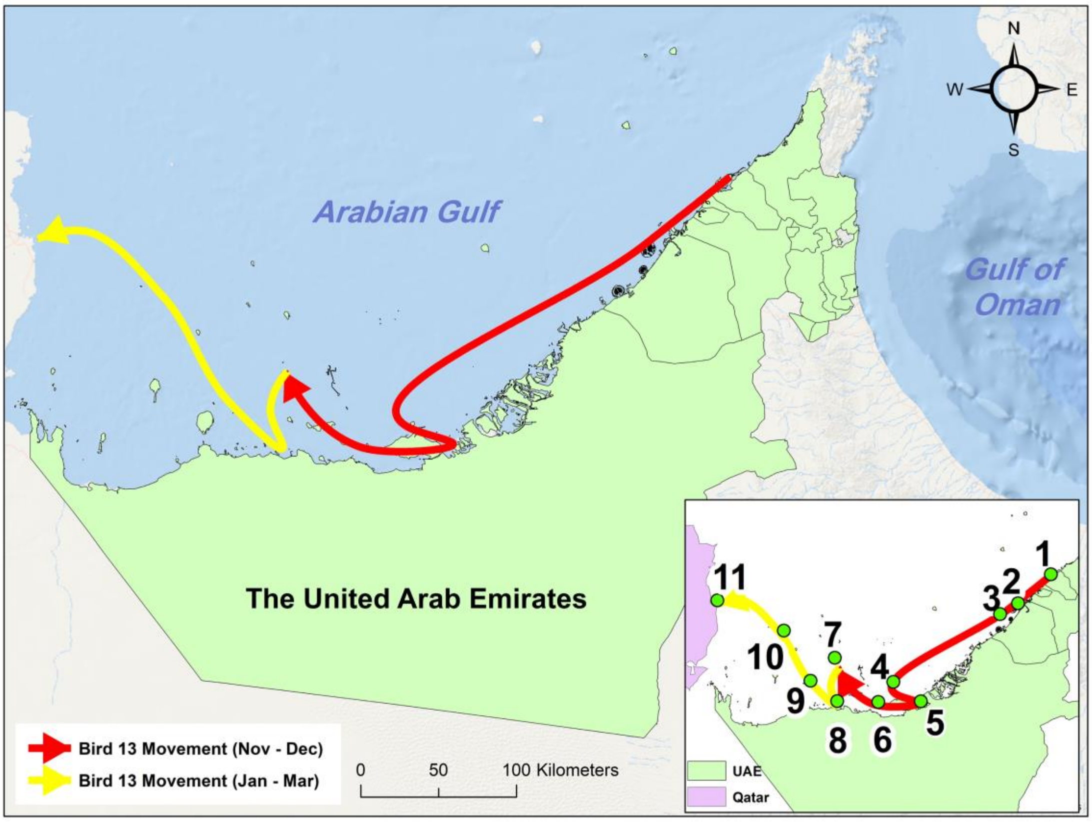

Figure 14: Bird 13 Movement during November and December 2014

Figure 15 shows the movement of bird 14. During November 2014, bird 14 was foraging in a wide range between Umm Al-Quwain and Abu Dhabi. Point 1 shows that bird 14 initiated the trip from Al Rafaah in Umm Al-Quwain, then it went close to Deira and the World Islands in Dubai. After that, it visited several sites in Abu Dhabi including Al Ma'Mourah (point 3), Al Dabiya (point 4) and Al Halah Island (point 5), By beginning of December 2014 until January 2015, the bird moved close to Zirku Island and Bu Tinah Island (point 6), then moved close to Al Bazm Al Gharbi and Sir Baniyas Island in Abu Dhabi (points 7 and 8). The bird returned back to Zirku and Bu Tinah Islands (point 6) by mid-March 2015.

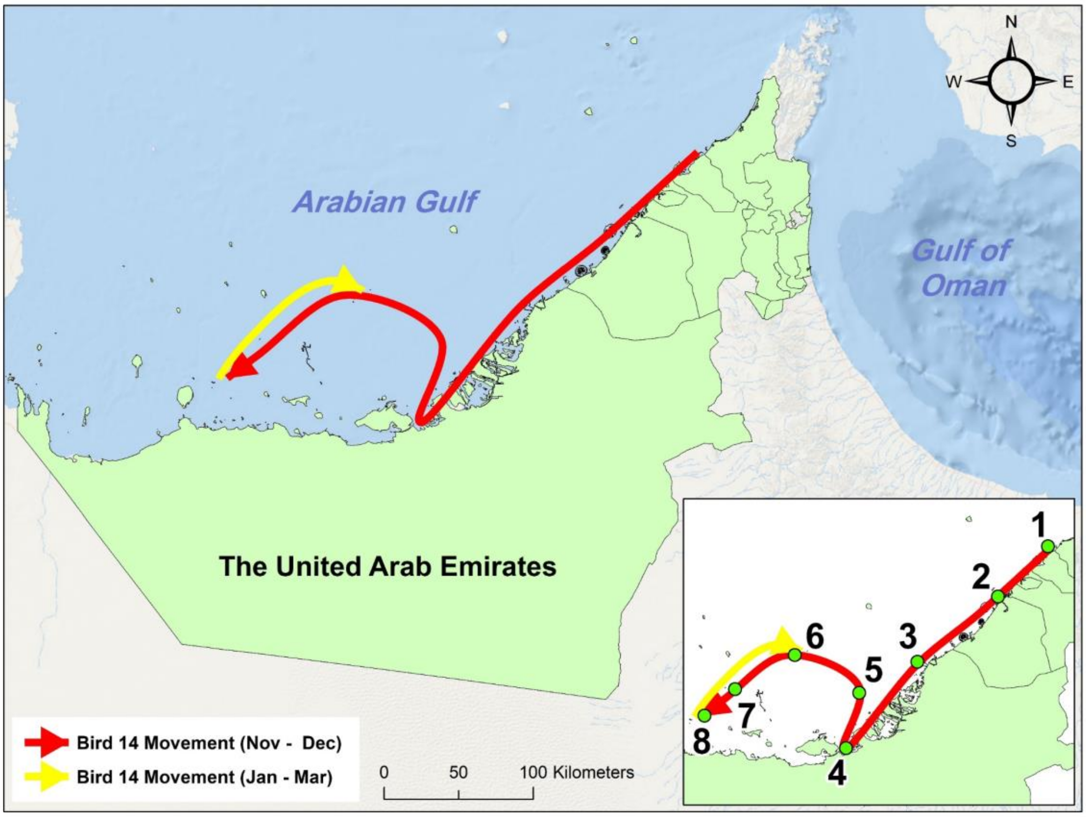

Figure 15: Bird 14 Movement during November and December 2014

Figure 16 shows 2 directional paths, one in December 2014 (red line) and the other in January 2015 (yellow line). During December, point 1 shows that bird 15 was in Siniya Island in Umm Al-Quwain, while point 2 shows that the bird went to Abu Al Abyad Island in Abu Dhabi. Then, point 3 shows that it moved close to Al Dabiya and Al Rafiq Islands in Abu Dhabi. After that, it moved to Bu Tinah Island in Abu Dhabi as shown in (point 4). However, from early January until mid of March, the bird went near Sir Bani Yas Island in Abu Dhabi, and from there it went to Doha in Qatar as seen in (point 6). By end of March the bird returned back close to Bu Tinah Island in Abu Dhabi and stayed there until mid of April. During May, the bird moved to Khasab in Oman (point 7). Finally, it went back to Al Riffa in Ras al Khaimah and stayed there until late July 2015.

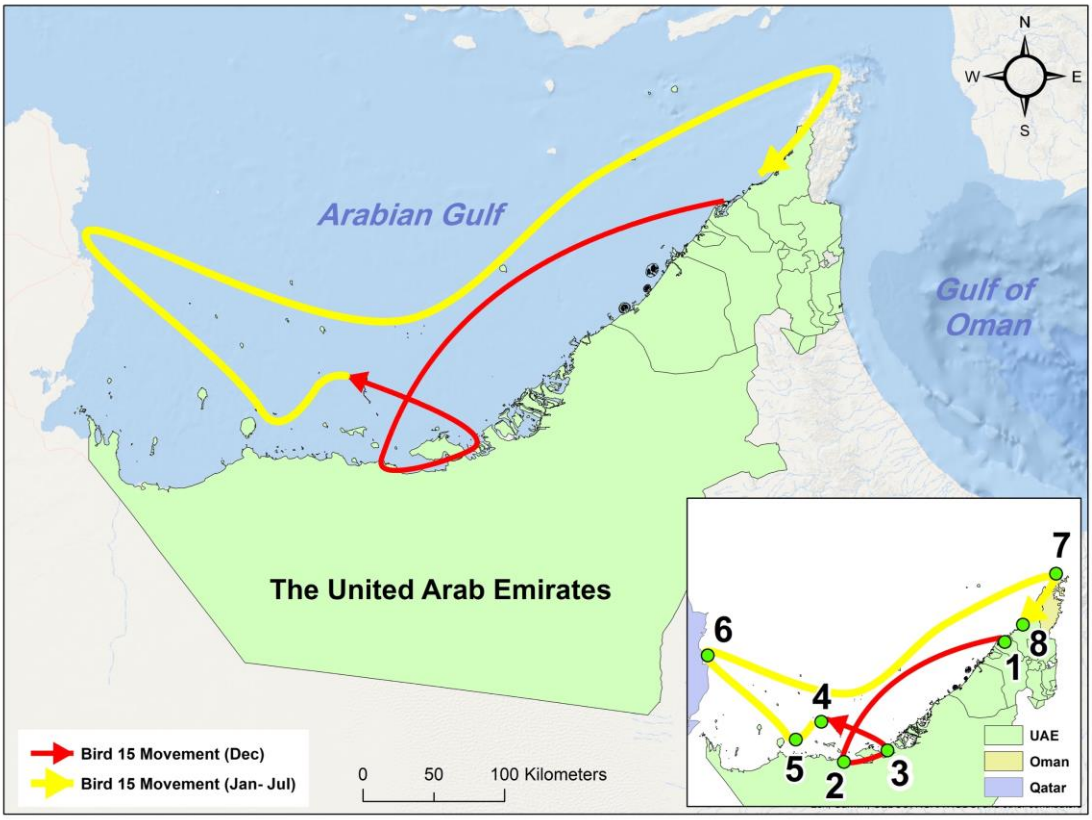

Figure 16: Bird 15 Movement during December 2014 - January 2015

Bird 16 movement is illustrated in Figure 17, all the GPS locations were collected in November 2014. Point 1 indicate that during November 2014, the bird was in Siniya Island in Umm Al-Quwain. Then, it went to the World Islands in Dubai (point 2). After that, it moved to Deira Islands in Dubai (point 3). Finally, point 4 shows that the bird returned back to the World Islands in Dubai.

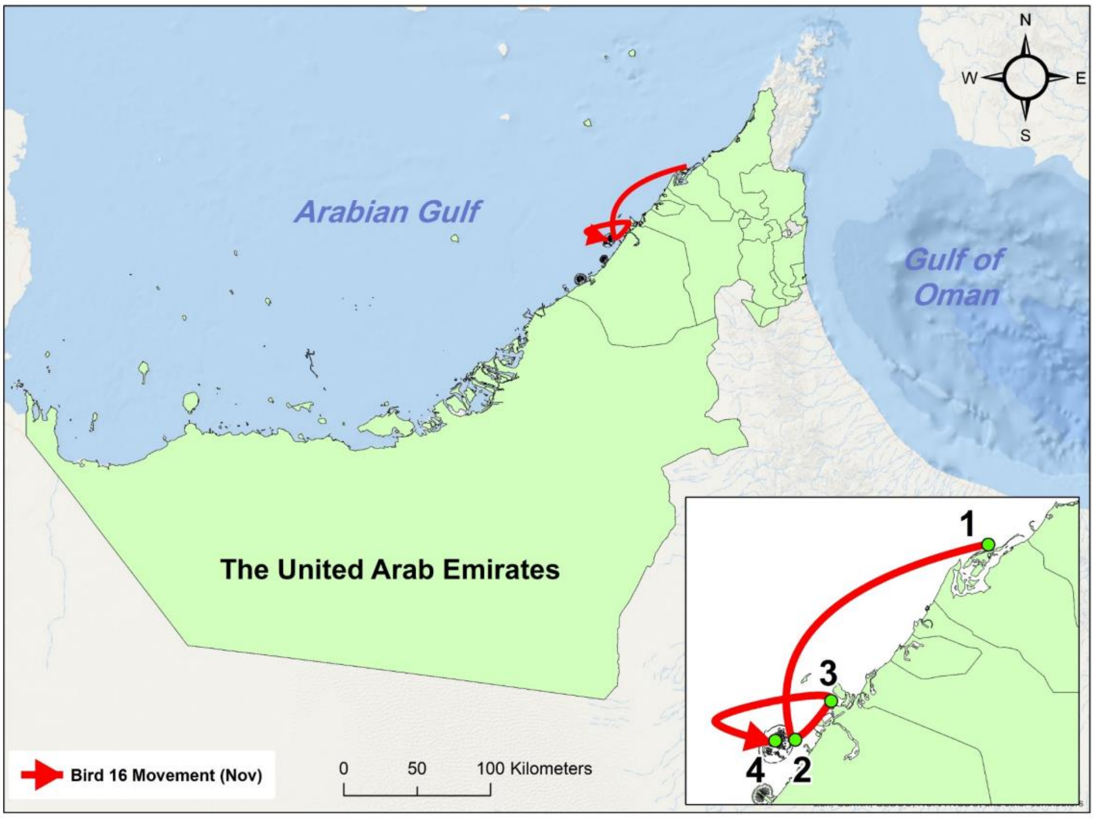

Figure 17: Bird 16 Movement during November 2014

Bird 17 movement is illustrated in Figure 18. Point 1 shows that in November 2014, the bird was in Ras Al-Khaimah. Then, it went to in Siniya Island in Umm Al-Quwain (point 2). Later on, the bird moved to Al Jirrī in Oman (point 3). By the end of November and beginning of December, the bird went to Kumzar near Ra's Shuraytah in Oman (point 4). Point 5 shows that during late of December 2014, the bird was in Kumzar in Oman. Then, it returned to Ras Alkhaimah in UAE during Januray 2015 as shown in point 6. In mid-January, the bird was in the World Island in Dubai as shown in point 7. Bird 17 flight for long distance far to Mirbah, Furjairah from late of January until mid-March.

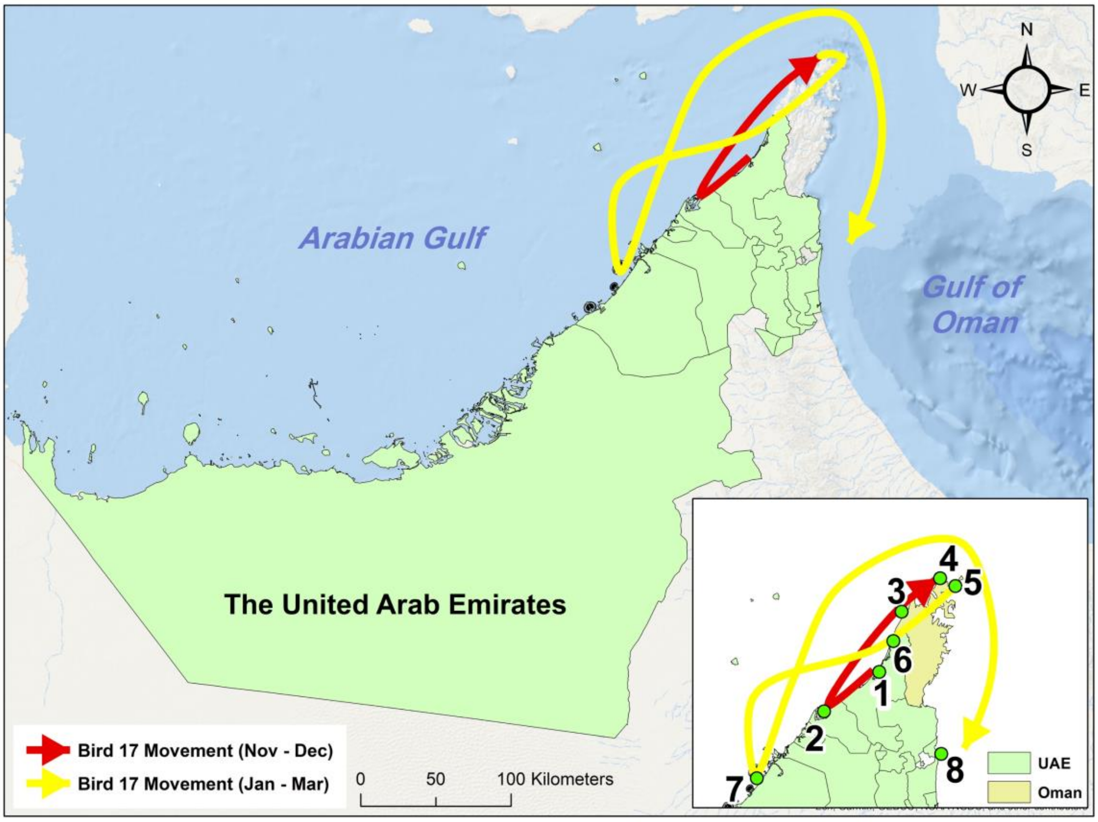

Figure 18: Bird 17 Movement during November and December 2014

Bird 18 has the largest data set, from November 2014 to August 2015 with 1857 GPS locations. As shown in Figure 19, bird 18 movement started in November 2014 from Siniya Island in Umm Al-Quwain (point 1). Then, it moved near to Deira Islands in Dubai (point 2) and stayed there until early December 2014. After that, the bird moved to visit several sites in Abu Dhabi. The first site is Al Dabiya (point 3), the second is Qassabi Island, the third is between Al Bazm Al Gharbi and Sir Baniyas Island (point 4), the fourth is in Al Shuweihat (point 5) and the last is in Bu Tinah Island (point 6). However, in January 2015, the bird went back to point 4 between Al Bazm Al Gharbi and Sir Baniyas Island, and it stayed there from January till April 2015. Finally, it moved toward point 5 which is Al Shuweihat until August 2015.

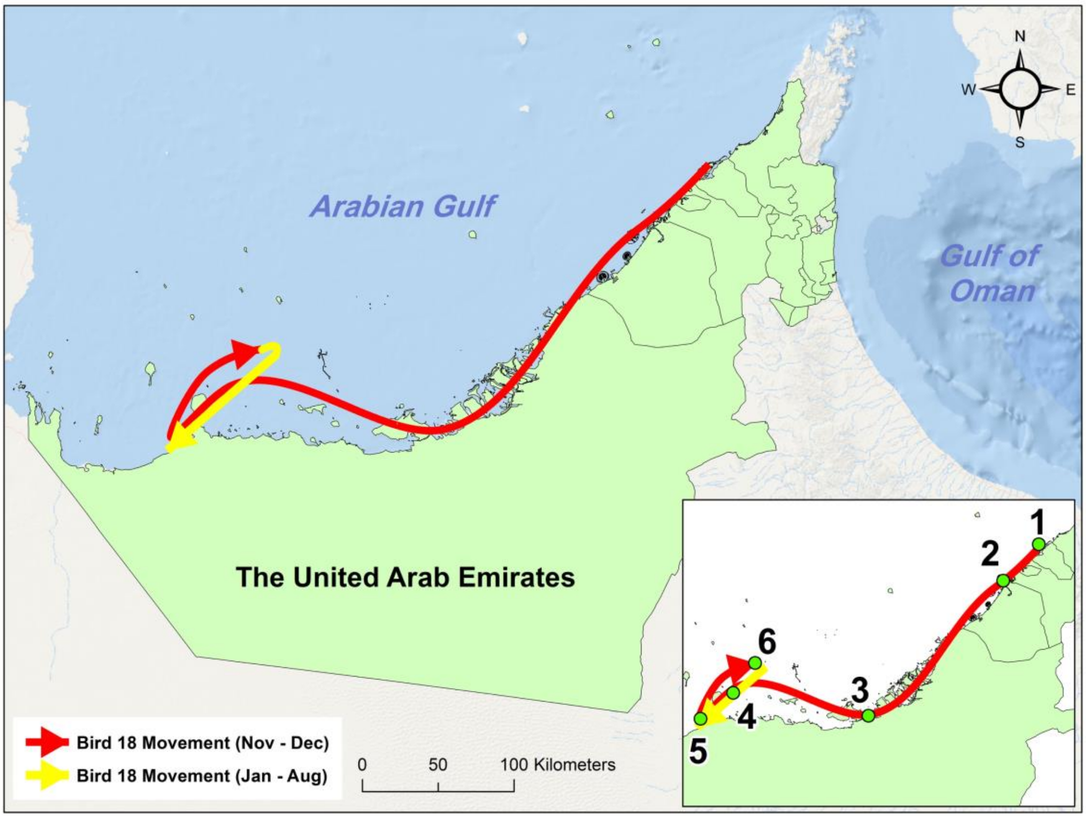

Figure 19: Bird 18 Movement during November and December 2014

2.4 Discussion and Conclusion

During both breeding seasons 2013-2014 and 2014-2015, Socotra Cormorants breeding on Siniya Island spent their entire annual cycle on the coast and islands of the Arabian Gulf and part of Gulf of Oman. In addition, it visited a variety of different coastal roosts and offshore island in both annual breeding cycle.

The PTTs generated rich data on the movement pattern and ecological behavior of the 18 individuals, which help us to understand the over view of Socotra cormorant movement behavior. It seems that Socotra Cormorants were seen foraging considerable distances away from Siniya Island. The birds were monitored foraged in one of three main areas: (i) adjacent to the Siniya Island in Umm Al-Quwain; (ii) adjacent to the Deira Islands and the World Islands in Dubai; and (iii) adjacent to areas in Abu Dhabi. These areas are close to the coast which are more likely linked with the shoals of migratory fish that have variable seasonal abundance (Muzaffar, 2014b).

Post-breeding migration started away from Siniya Island in late November, which indicate shortage in local fisheries (Muzaffar et al., 2017a). This is forcing birds to fly to the regions that are more distant, such as Deira Islands which is about 50 km away from Siniya Island, or even farther to Qatar coastal area (west UAE), and Oman coastal area (east UAE) which is usual in seabirds.

A total of 18 Socotra Cormorants were under study in this chapter to indicate their movements during the 2 years of breeding seasons (November /December 2013-2014 and November/ December 2014-2015). Birds 1, 2, 3, 4, 5, 6, 7 and 8 were studied in the first year of breeding season. Most of their movements started from Siniya Island in Umm Al-Quwain in November 2013 moving toward Abu Dhabi during December 2013. Except for bird 1, its movement started from Deira Islands in Dubai and moved toward Abu Dhabi, and bird 2 moved in the opposite direction although it started from Siniya Island in Umm Al-Quwain. Bird 2 moved toward Ras Al-Khaimah contrary to the other birds in the first breeding season.

Birds 9, 10, 11, 12, 13, 14, 15, 16, 17 and 18 were studied in the second year of breeding season (November/ December 2014-2015). Very similar to the first year, most of the birds started from Siniya Island in Umm Al-Quwain, except bird 12, it stared from the World Islands in Dubai, and bird 17 started from Ras al Khaimah. However, it seems that in the second period (January 2014- August 2015) of the second year the bird preferred long distance trips. The longest trip illustrated by bird 15, foraged in 3 countries (UAE, Oman, and Qatar). As birds 9, 12 and 15 reached Oman coastal area. Birds 13 and 15 reached also Qatar coastal area. Whereas, bird 11 moved short distant around Siniya Island in Umm Al-Quwain.

Thus, conservation of the species will therefore require commitment from different jurisdictional authorities, namely, the Ministry of Climate Change and Environment (UAE), Environment Agency Abu Dhabi, the Dubai Municipality, Ajman Municipality, Ras Al Khaimah Environment Protection and Development Authority, Sharjah Environment Protection and Development Authority and Fujrairah Municipality, along with the Omani Ministry of Environment and Climate. Through collective agreements based on the science, it will be possible to develop a conservation plan to protect the species from further declines, by protecting vital areas to reduce the threat and increase the stability of Socotra Cormorant population. With increasing vessel activity, there may be continuous disturbance on foraging areas. Formulation of guidelines targeting the behavior of recreational or fishing vessels when approaching large concentrations of foraging cormorants could be an important first step. Furthermore, studies need to identify the types of fishing gear that are most detrimental to cormorants and gradually reduce or eliminate their use (Muzaffar, 2014a).

Chapter 3: Correlation between Marine Ecosystems and Migration of Socotra Cormorants in Arabian Gulf

3.1 Introduction

3.1.1 Mangroves

Mangrove habitats are vital marine ecosystem, that provide food, shelter and nursery areas for a variety of terrestrial and marine fauna. It supports a wide range of important species such as fish, shrimps, turtles, and significantly contributes to the coastal area productivity. The distribution of mangroves forests serves is an important habitat for many bird species and support permanent and migrant bird colonies (Al-Maslamani et al., 2013).

Several authors have reported contradictory findings about the number of waterbirds in mangrove forests, which indicate that it is extremely hard to find the comparison of waterbird diversity among the mangroves. This is explained by the differences between the nutrient cycles and physical structure of the surrounded environment. Nevertheless, the patterns of resource availability have an effect on diversity of waterbird species in mangroves (Ghasemi et al., 2012).

Seabird have a significant effect on mangroves, they can transport marine nutrients in the form of guano to terrestrial and coastal ecosystems, which is enrich surrounded ecosystems (Adame et al., 2015). Though, seabird used as biomonitoring tool to evaluate the status and changes in mangroves (Ghasemi et al., 2012).

Mangroves covers the Arabian Peninsula coastal areas and it is considered as one of the driest and least diverse mangrove habitats in the world (Moore et al., 2014). Mangroves forests provide a variety of ecological serves and economic values, from the valuable fisheries, birds and marine wildlife shelter to shoreline protection from storms, erosion, and sedimentation.

UAE Mangrove forests are composed of highly salt tolerant gray mangrove that have a patchy distribution along coastal area. Abu Dhabi, Khor al Bazm Sabkha and Sinaiya Island form a significant stands of mangroves in UAE. There are two mangrove species occupying, Avicennia marina and in 1984, Rhizophora mucronata was re-introduced (FAO, 2007).

Based on aerial imagery data sets survey of Mangroves in the United Arab Emirates during December 2011 and May 2012, it shows that, in total, approximately (13,616 ha) of mangroves. The majority of this total (10,834 ha) is localized in the largest emirate, Abu Dhabi. While the next mangrove-rich emirate is Umm Al Quwain, with approximately (1877 ha) (Moore et al., 2014).

3.1.2 Coral Reefs

Coral reefs are highly rich ecosystem that provides a variety of ecological services such as ultimate sources of seafood, biological and habitat diversity, recreational values, and economic benefits (Naser, 2014).

Coral reef habitat occurs in coastal areas throughout the UAE, with coral habitat found in all seven emirates. The total area of coral habitat is (13,000 ha). More than 90% of UAE's coral reefs are in the Arabian Gulf (Grizzle et al., 2016).

Coral reefs of the UAE were extensive in northeastern Arabia. Over the past several decades there has been rapid degradation of coral reefs across the UAE, it is estimated that almost 70% of original reef cover in the Arabian Gulf may be considered lost and a further 27% are threatened or at critical stages of degradation (Wilkinson, 2008).

Rapid degradation is a result of increasing natural and anthropogenic stressors, such as extremes in temperature, salinity and other physical factors in the Arabian Gulf that restrict the growth and development of corals (Grizzle et al., 2016). Despite these harsh environmental conditions, corals in the Arabian Gulf exhibit significant resilience and vitality. Also, many nearshore reefs have been reclaimed along the coastline of the Arabian Gulf.

Overall, coral distribution pattern in the Arabian Gulf indicates a greater concentration of coral habitat in central and western Abu Dhabi compared to other areas. Abu Dhabi, occupied by 7951 ha of coral reefs. In Ras Ghanada, Yasat Island and Dalma Islands elsewhere, the coral cover remains very low in last 10 years due to natural and human stresses (Wilkinson, 2008).

Other significant concentrations of coral reefs are on the east coast of Ras Al Khaimah that occupied 2306 ha of coral reefs, and in the extensive lagoon system in Umm Al Quwain that covers around 1577 ha (Grizzle et al., 2016).

UAE coastline have geographic differences in benthic composition and coral community structure. However, reef benthos dominated UAE coastal area with a mixture of live coral and algae-covered dead coral skeleton. (Grizzle et al., 2016).

3.2 Methods

To study the correlations between the distributions of Mangroves and Coral reefs with the movement of Socotra Cormorant, the data were obtained from different source. Mangroves areas, coral reefs points, and important bird area were obtained from Ministry of Climate Change and Environment (MOCCAE). The Marine protected areas data were obtained from Abu Dhabi Environmental Agency website. All data were gathered and analyzed using ArcMap Software (10.5). To identify the correlations between the distributions of Mangroves and Coral reefs with the movement of Socotra Cormorant, buffer zones were created using 1 km distant. Also merge buffers were created by using 2 km distance to highlight overlayered significant areas, which helps to identify the suggested protected areas.

3.3 Results

All bellow maps were generated using ArcMap Software (10.5), which illustrated the distribution of Coral reefs, Mangroves area and Socotra Cormorant foraging areas, and highlighted the suggested protected areas for Socotra Cormorants which is a useful conservation tool for future planning.

Figure 20 shows the distribution of mangroves and coral reefs in UAE coastal areas. The figure indicate that the corals area is spread more than the mangroves areas. Mangroves area are more abundant in Abu Dhabi than other emirates, and then, Umm Al Quawain comes in the second abundant emirate.

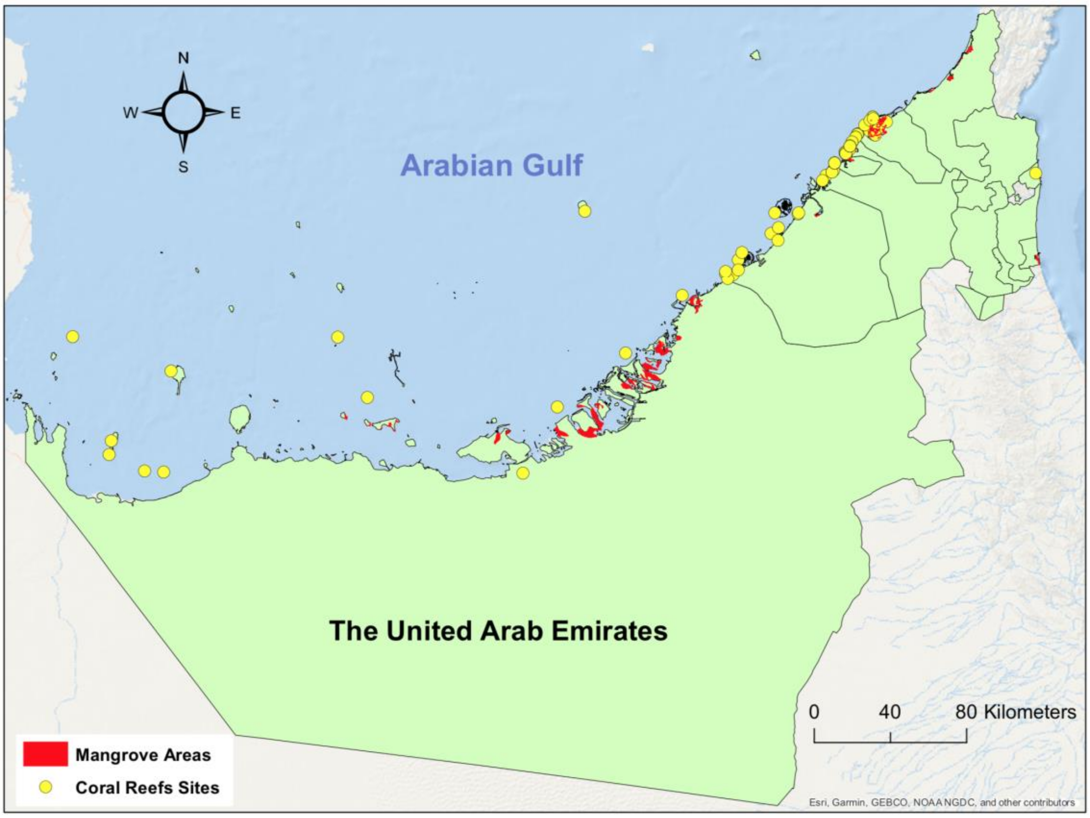

Figure 20: Distribution of Mangroves and Coral Reefs in UAE Costal Area

Figure 21 shows that there are 11 sites of Socotra Cormorant foraging area, 4 of these sites are mangrove areas, 1 is located in Siniya Island Umm Al Quawain, 2 sites are located in Ras al Khaimah, and 1 site is closed to the biggest mangrove area in Abu Dhabi. However, from the 11 sites of Socotra Cormorant foraging area, 3 of these sites are coral reefs sites, 1 is located in Siniya Island Umm Al Quawain and 2 sites are located in Dubai.

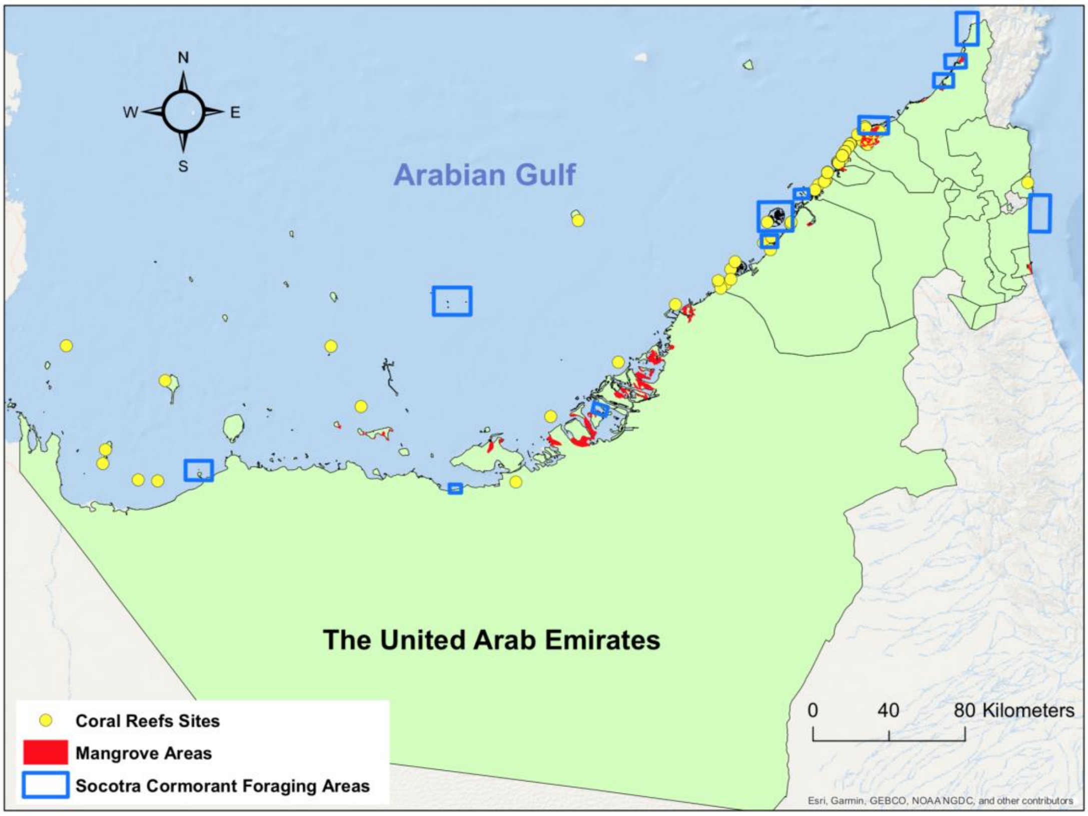

Figure 21: Distribution of Coral Reefs, Mangroves Area and Socotra Cormorant Foraging Area

Figure 22 shows the distribution of coral reefs and mangroves along the UAE coastal areas. The movement of Socotra Cormorant along the UAE coastal areas and marine protected area are declared by EAD. The bird important areas in UAE are published by MOCCAE. There are 6 marine protected areas that represents 13.4% of Abu Dhabi's marine areas. (1) Al Saadiyat Marine National Park located in the marine area adjacent to Saadiyat Island with a total area of 59 square kilometers. (2) Al Yasat Marine Protected Area about 2046 square kilometers and it is surrounded by coral reefs which act as important marine sanctuaries to many species. (3) Mangrove National Park with a total area of 10 square kilometers that is covered by millions of mangrove trees and the park is adjacent to the eastern mangrove corniche. (4) Marawah Marine Biosphere Reserve, and it covers a total area of about 4,255 square kilometers. It is rich in biodiversity, supported by marine and coastal environments, and it is home of the second largest community of dugong in the world. (5) Bul Syayeef Marine Protected Areas, covering a total area of 145 square kilometers. It is located west of the Mussafah channel and is an important area for migratory and resident birds. (6) Ras Ghanada Protected Areas, located in the marine area adjacent to Ras Ghanaada, covering a total area of 55 square kilometers, and it is surrounded by coral reefs. Figure 22 illustrate 23 important birds' areas, 6 out of 23 are declared as marine protected areas by EAD, while 16 area are not declared yet. MOCCAE mentioned in their report, 23 out of 30 are marine important birds' areas, which are Abu Al Abyad Island, Abu Al Sayayif, Al Rafiq, Al Ushsh Island, Al Zora (Khor Ajman), Alqurm Wa Lehfeiyah (Khor Kalba), Balghelam, Bu Tinah, Dinah (Dayyinah), Faziya, Ghaghah Islands, Khor al Beideh, Khor Muzahmi (Al Jazirah Khor), Marawah Island, Muhaimat Island, Qarnain Island, Ras Al Khor Wildlife Sanctuary (Khor Dubai), Salahah Island, Siniyah island, Sir Bani Yas Islands, Sir Bu na'air Island, Umm Amim, Yasat islands.

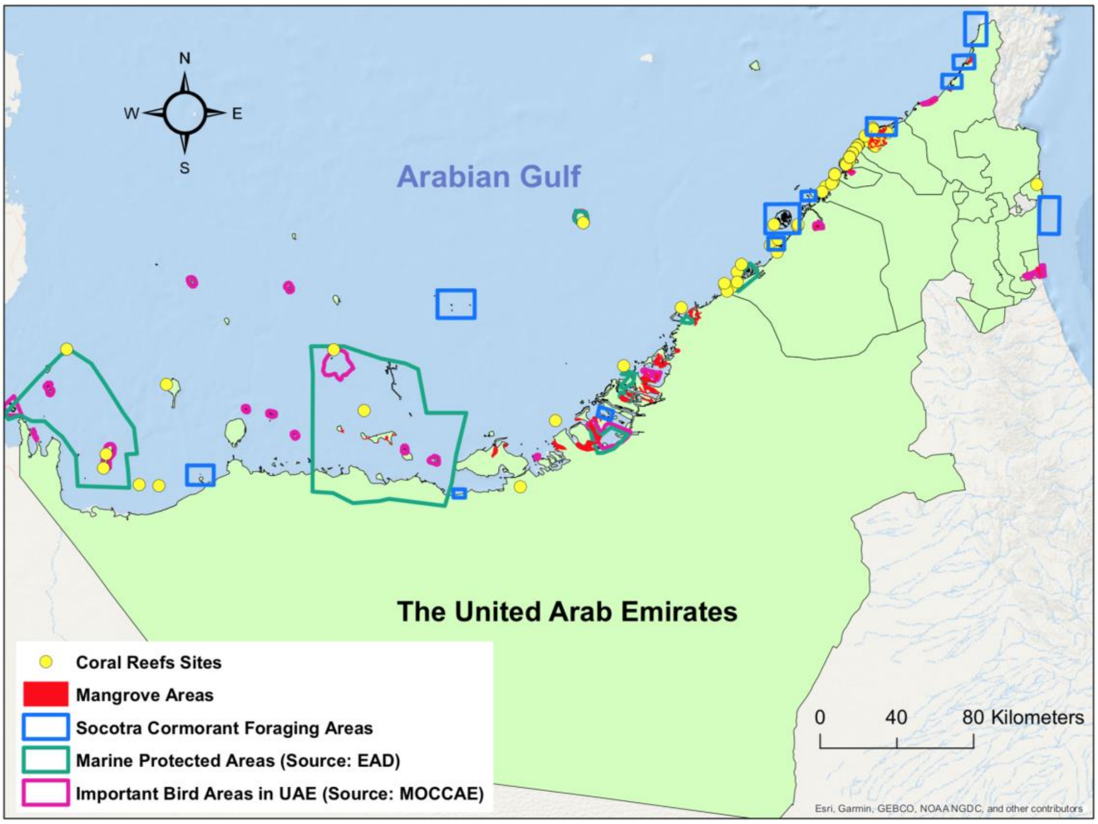

Figure 22: Distribution of Coral Reefs, Mangroves Area and Socotra Cormorant Foraging Areas, Marine Protected Areas, Important Bird Areas in UAE

Figure 23 shows the area with coral reefs and mangroves that are intersected with the existence of Socotra Cormorants. Point 1 and point 2 are located in Ras Al Khaimah. Point 3 is located in Siniya Island which is covered by coral reefs and subtropical & tropical mangrove forest. Point 4 and point 5 are located in Dubai. Point 4 is the World Islands and point 5 is the Palm Island. Both are surrounded by man-made coral reefs.

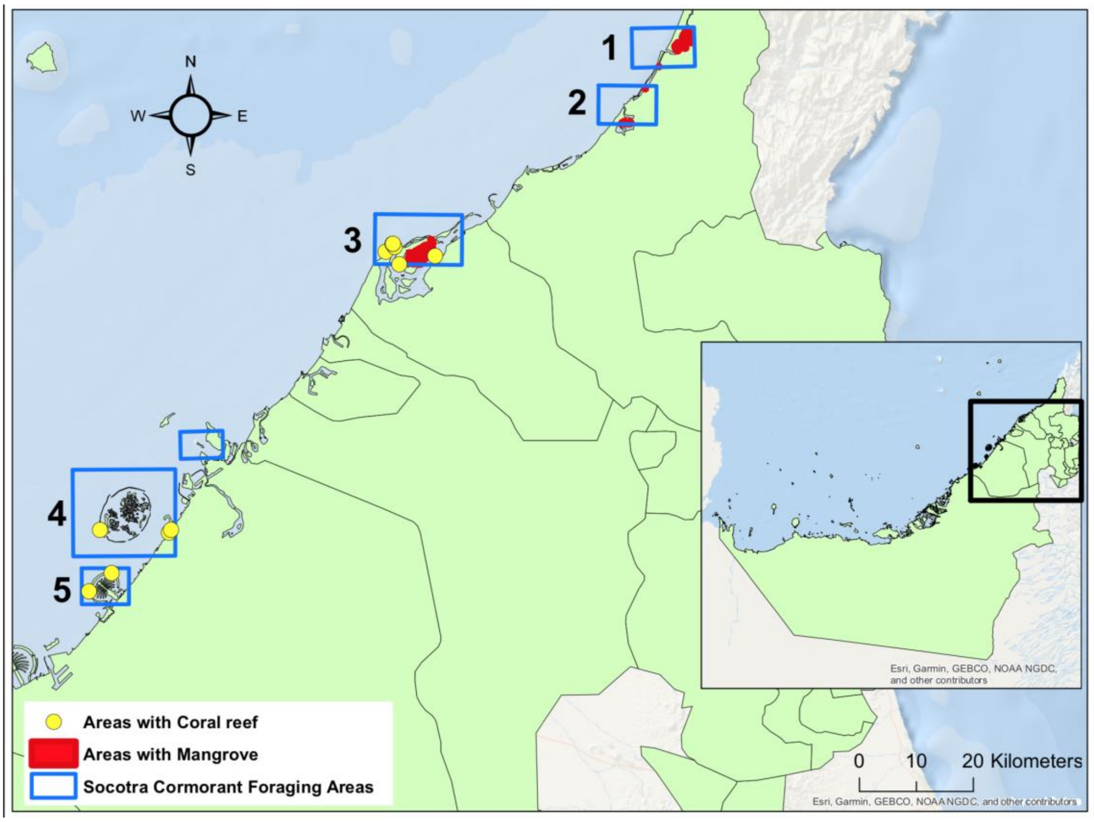

Figure 23: Distribution of Coral Reefs, Mangroves Area and Socotra Cormorant Foraging Areas in Northern UAE

Figure 24 shows the important areas for Socotra Cormorants which are recommended to be protected, due to its vital value for the foraging behavior. One of these areas is Siniya Island, and it is a critical area that needs to be declared as protected area because it is a largest breeding colony of Socotra Cormorant in UAE.

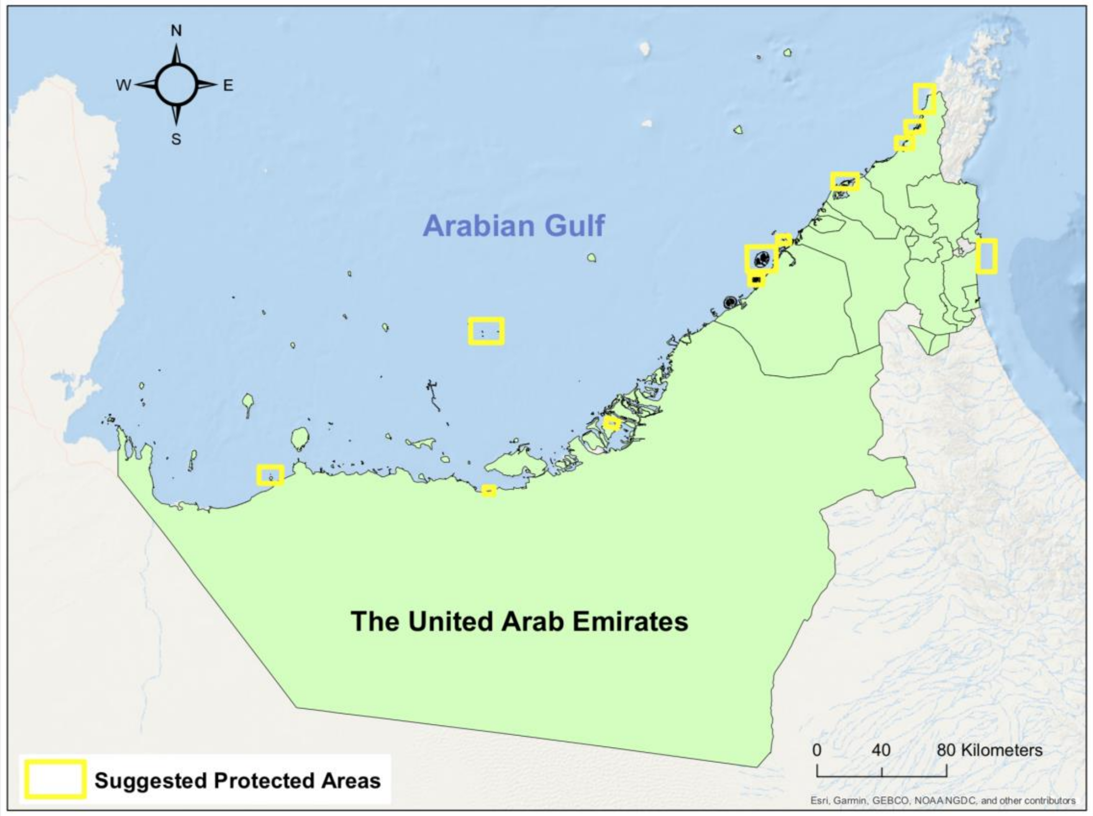

Figure 24: Suggested Protected Areas for Socotra Cormorants

3.4 Discussion and Conclusion

The results of this study provide important information on the current distribution of Socotra Cormorant along with the distribution of marine ecosystems (mangrove and coral reefs), allowing for improved management of these important ecological assets. The results show that there are 11 sites of Socotra Cormorant favorable foraging area, out of these sites, there are 5 only having mangroves and coral, 2 sites are mangroves area, 2 sites are coral area, while 1 site have both mangroves and coral which is Siniya Island. Siniya Island is a significant area for Socotra Cormorant, and it have an ecological value, thus it should declare as protected area.

Table 1: Socotra Cormorant Favorable Foraging Sites in UAE

	Site name	**Emirates**	**Habitat**
1	Shuweihat Island	Abu Dhabi	n\a
2	Khor AlBazim	Abu Dhabi	n\a
3	Al Futaisi	Abu Dhabi	n\a
4	The Palm Jumeirah	Dubai	Coral reefs
5	The World Islands	Dubai	Coral reefs
6	Deira Island	Dubai	n\a
7	Siniya Island	Umm Al Quwain	Coral reefs, Mangrove
8	Al Rams	Ras Al Khaimah	Mangrove
9	Hulaylah	Ras Al Khaimah	Mangrove
10	Al jeer	Ras Al Khaimah	n\a
11	Al Qurayya	Fujairah	n\a

Table 1 summarizes Socotra Cormorant favorable sites in UAE. This indicates that mangroves and coral reefs areas are favorable environment for Socotra Cormorant, but there is no significant correlation between the movement of Socotra Cormorant and the distribution of both mangroves and coral reefs. Nevertheless, the existence of these ecosystem supports the marine life which indirectly supports seabirds such as Socotra Cormorant.

Chapter 4: Discussion and Conclusion

4.1 Discussion and Conclusion

To understand the over view of Socotra Cormorant movement behavior and the relation of the movement pattern and ecological distribution of marine ecosystem, GIS was used. Field studies of group foraging are challenging, the existing biologging technology represents an efficient and cost-effective solution. The results indicate that Socotra Cormorants were seen foraging considerable distances away from Siniya Island in post breeding season (late November) adjacent to Deira Islands and the World Islands in Dubai, and to areas in Abu Dhabi. Also, the study shows that Socotra Cormorant moved to two distinct directions, to the east toward Oman and to the west toward Qatar across most of UAE coastal area. Therefore, conservational efforts and management plans required commitment from different jurisdictional authorities to protect the endemic species from further declines.

Also, the results of this study provide much needed information on the current distribution of Socotra Cormorant along with the distribution of marine ecosystems (mangrove and coral reefs). In addition, it support the study that demonstrates a correlation and answer the main question of this research successfully that there is no correlation between the movement of Socotra Cormorant and the distribution of both mangrove and coral reefs. However, the existence of these ecosystems supports the marine life and the stability of coastline.

All the results are considered significantly important for conservation efforts. It can be used as a tool to declare new area as a protected area, such as Siniya Island, due to its ecological important. This area consists of Mangroves area and coral reefs, along with well-established colony of Socotra Cormorant. It is as essential area for all

Socotra Cormorant foraging trips starting and returning point. Conservation measures must account the extreme sensitivity of many seabirds by human disturbances. In some cases, total exclusion of humans may be required; in others, limited access might be possible under closely managed conditions at certain times of a year. A symbiotic relationship between seabird conservation, legitimate research and tourism should be the desired goal to create a balance between human development and seabird population stability (Anderson & Keith, 1980).

Four areas may be identified for conservation purposes: (i) conservation of breeding colonies; since Socotra Cormorant are endemic to specific region, the breeding colony is highly recommended to be protected in order to avoid population decline. (ii) conservation of roosting areas; many islands and cliffs are used by Socotra Cormorants for roosting and resting in the post-breeding period. Since these islands are away from the breeding colonies, it must be under protection. (iii) conservation of foraging areas; preliminary data shows that Socotra Cormorants breeding on Siniya Island forage either northeastwards or westwards during the breeding seasons, covering distances up to 10-70 km. Thus, conservation efforts must ensure that areas close to the coast are protected. (iv) public awareness, UAE government is committed to protecting natural resources and maintaining habitat for wildlife, on the other hand, fisherman should be aware of the law and regulation, also that Socotra Cormorants are not depleting the local fisheries (Muzaffar, 2014a).

All conservation areas are in line with this commitment and may help to protect not only the Socotra Cormorant, but many other species that co-exist in the Arabian Gulf (Muzaffar, 2017b).

Future studies should be conducted to know the current movement pattern of Socotra Cormorant, the existing of Abu Dhabi colony and understand the movement pattern. Also, it is important to understand the relation between the biotic factors of Arabian Gulf and the migration tigers of Socotra Cormorant. All these questions might give a clear view of the movement pattern.

The challenges and limitation were to have new data on the current movement pattern of Socotra Cormorant due to authorization of the protected Island and weather disturbance during November and December. Moreover, to study animal behavior, the time frame should cover 5 breeding cycle, which is not applicable in the current study.

In conclusion, Socotra Cormorants occur in significant breeding concentrations in the western and eastern Arabian Gulf, and despite declines since the 1960s (Muzaffar, 2014a). Conservation and management of such populations must focus on eliminating disturbance during breeding seasons, controlling invasive predators, engaging local fishermen to reduce by-catch mortality, protecting coastal areas to safeguard foraging sites, and creating awareness.

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