Management of Animal Ecology and Adaptation to Climate Change in the Iraqi Marshlands

A thesis submitted by

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Abstract

Climate change has become a global threat. Its impact on natural ecosystems, ecosystem services, infrastructure, livelihoods, and socio-economic systems requires rapid implementation of local adaptation strategies. Iraq's natural ecosystems are already under pressure due to water scarcity. Climate change is expected to be an additional strong stressor on Iraq's natural ecosystems. However, there is a clear lack of academic studies that evaluate Iraq's vulnerability to climate change. This thesis presents an analysis of the potential impact of climate change on Iraq's first protected area, the Mesopotamian Central Marsh (CM) as a case study. Exposure and vulnerability of the CM site and key taxonomic groups (birds and Soft-Shelled turtle *Rafetus Euphraticus*) were analysed to evaluate the potential impact of climate change and used to create suggestions for adaptation. The CM is highly exposed to predicted changes in summer temperature, but less exposed to predicted future rainfall changes. Our results also showed the highly vulnerability of the CM to climate change at the site level, suggesting that the Marsh Arab people (Ma'adan) and their water buffalo are the most vulnerable components in the site. In addition, resident, summer visitors, and breeding bird species were indicated as highly vulnerable to climate change. The results also highlighted the CM site as a hot spot area for breeding of the endangered species *Rafetus Euphraticus* with maximum population size of 212 - 283 individuals/141,615 ha. The CM currently suffering from water scarcity and salinity, and could be changed to a novel regime under the scenario of climate change impact. In this case, the estimated economic lost and damage in the CM could be 90,000.00 USD for the whole area of the 300,000-ha site according to the estimation of (Sukhdev et al., 2010) or could be 860,078.23 USD/40,000 ha according to our estimation.

Dedication

This thesis is dedicated to:

Soul of my grandfather, Fazaa,

my father and mother.

My wife, children, and brothers

My great country IRAQ

Acknowledgements

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All the field work were collected by the author unless otherwise stated. Soil samples and water samples were sent to the Centre of Environmental Research at the University of Technology in Baghdad.

Publications

Chapter 3 was published in the conference proceedings from an International Conference on Latest Trends in Food, Biological & Ecological Sciences (ICLTFBE) in 2015. Chapter 2 was published in the International Journal of Biodiversity in 2017 (vol 2017, article 4198690).

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Chapter 1. Introduction

This thesis is focussed on a region of Iraq that is of great historic and environmental importance. I thus begin with a description of the study region to place the work in context.

1.1 Mesopotamian Marshlands

The Mesopotamian Marshlands originated during the Holocene era 10,000 years ago. Before that time, the marshlands may have been a saltwater area with the same characteristics and functions (Evans, 1994). Archaeological finds and artefacts from Iraq described the Mesopotamian Marshlands during the Sumerian era (3000 BC; e.g. the epic of Gilgamesh, the world's first epic poem, described Gilgamesh with water buffaloes in the Tigress and Euphrates), and current studies have indicated that Arab marsh dwellers are still using the same boats and lifestyle as their ancient ancestors. In addition, clay tablets from the Sumerian era documented the environment and wildlife of the marshlands in the same areas that exist today (Nature Iraq, 2006a). The marshlands area relied throughout the centuries on the flooding of the Tigress and Euphrates Rivers, hence, its area shrank and increased according to the rivers' flooding intensity and ability of people to control the water. The most important steps in controlling the water from the Tigress and Euphrates Rivers that led to decreases in flooding in Iraq including the marshlands were taken in the 20th century (Al-Ansari, Knutsson and Ali, 2012).

1.1.1 *Historical environmental challenges in the Mesopotamian Marshlands*

The Mesopotamian Marshlands are located in the south of Iraq (29°55'00"N to 32°45'00"N and 45°25'00"E to 48°30'00"E) and are considered one of the biggest and ancient wetlands in the Middle East (Scott and Evans, 1993; Scott, 1995;

Partow, 2001; Nature Iraq, 2006b, 2006d). The habitat provided by the marshlands ecosystem has always supported local people and a significant population of wildlife (Nature Iraq, 2017). The Mesopotamian Marshes consist of three main marshes: Central Marsh, Al-Hawiza Marsh, and Al-Hammar Marsh (10,000 km^2 during 1970s; Figure 1.1). The natural systems of the Mesopotamian Marshlands have faced significant challenges during the 20th century. Dam construction inside Iraq and upstream countries, irrigation projects for agriculture, petroleum development, wars and drainage programmes were the most important problems that faced the marshlands until 2003. Since then, the area has faced different additional environmental challenges and unique problems for each marsh separately (Partow, 2001; Nature Iraq, 2006b).

Although dams have played an important role in protecting the land of Iraq by controlling flooding, they have had negative impacts on the marshlands by shrinking its area and preventing the natural accumulation of sediments in the marshes, which occurred historically (sediment that came from upstream Tigress and Euphrates Rivers made the marshlands' soil very fertile and suitable for agriculture; Nature Iraq, 2006d). Dam construction started early in the 20th century (e.g. inside Iraq Al Hindiya dam was constructed in 1913 and Al Kut dam in 1938). However, the South-eastern Anatolian (GAP) project in Turkey that started in 1977 had the most significant effect on the water flow of both Tigress and Euphrates Rivers as discharge in the Euphrates was cut in half since 1990, while discharge was cut by a third in the Tigress during the same period (Nature Iraq, 2006b). Twenty-two dams and nineteen hydraulic power plants were included in the GAP project to irrigate an area of land 17,103 km^2 in area and with a total storage capacity of 100 km^3. The storage capacity of the GAP project is three times the capacity of reservoirs in both Iraq and Syria before 1990 (Al-Ansari and Knutsson, 2011).

Although agriculture was started 6000 years ago in the marshlands, this activity is now one of the major problems that faces the marshlands in the 20th century. Large numbers of agricultural irrigation channels were implemented in Iraq to support agriculture; hence, runoff of agriculture has affected the natural features of the marshes. In addition, the government converted part of the marshlands to be used as agricultural areas. As a result, the concentration of salinity, pesticides, and nutrients have increased significantly in the water of the marshes (Nature Iraq, 2006d). Oil in the south of Iraq makes up 5% of the world's oil reserves. Oil was discovered in 1920 and since that time five large oilfields have been established inside and around the marshlands area: South and north Rumayllah, and Zubayr oil fields in Hammar Marsh, West Qurna in the Central Marsh, and Majnoon in Hawiza Marsh (Nature Iraq, 2006c), hence, since the time of oil establishment 10% of the total historical area of the marshlands has been lost.

War that occurred between Iraq and Iran from 1980 to 1988 was an additional negative impact on the marshlands. Major damage due to war impacted the Haweiza Marsh whose area was dried and flooded several times and used for military purpose. In addition, a long road was paved in the middle of the Central Marsh for the same reason. On the other hand, Gulf war one in 1991 and two in 2003 did not directly affect the marshlands (Partow, 2001; Nature Iraq, 2006a). Eight large hydraulic projects (Main Outfall Drain (MOD), Qadissiyah River, Mother of Battles River, Euphrates Levees, Loyalty to Leader Canal (Sweet Water Canal), Crown of Battles River, Earthen embankments, Canal of East – West the Glory River) were implemented during the 1990s to drain the marshlands by the Iraqi government for several reasons related to agriculture and politics (Nature Iraq, 2006b). The drought programme converted the marshlands to a desert in 2002 apart from 14% (only 1,600 km^2 of the marshes were alive) of its original 1970 area, and the local human population decreased from 500,000 to 85,000 (Nature Iraq, 2006d).

Despite much political support by the new Iraqi political regime formed after the 2nd Gulf war in 2003-ongoing and an enhanced budget to restore and rehabilitate the Mesopotamian Marshlands, the environmental challenges and problems of the marshlands were not solved properly and the area has been facing new additional challenges (Al-Ansari, Knutsson and Ali, 2012; Douabul *et al.*, 2012). The restoration process started in the end of 2003 by breaking and opening the soil embankments that surrounded the marshlands to let the water of the Tigress and Euphrates Rivers cover the land of the marshes. However, this action was not enough to restore the size of the marshes to their previous 1970s extent due to water scarcity in the Tigress and Euphrates Rivers. Only 40% to 58% of the historical area was re-flooded at the end of 2006 and August 2007 respectively (Nature Iraq, 2006c). Another severe situation faced the marshlands between 2008 and 2010 due to water scarcity in the Tigress and Euphrates Rivers, which significantly affected the connection between the marshlands' water bodies, creating a clear separation between the main three large marshes and unique problems for each marsh (Douabul *et al.*, 2012). As a result, local actions for each marsh were adopted by the Iraqi government and local authorities to restore the marshes and use their services sustainably. Huge efforts need to be spent by the government and local people to address and highlight the marshlands' problems and find suitable solutions for the future.

1.2 The Central Marsh

Information and data about the marshlands from the 1970s-time period has been selected as a reference for restoration goals that were adopted by the Iraqi government after 2003 (Nature Iraq, 2006a). The Central Marsh (46◦ 59.33 East 30◦ 57.53 North) during the 1970s was surrounded by the Tigress River from the east and north, and the Euphrates River from the south, and located between three provinces: Missan in the north, Thi – Qar in the south and west, and Basrah in the south and east. The area of the marsh covered 3000 km^2 in the 1970s and received water mainly from the Tigress River. The marsh contained dense aquatic plants and several permanent freshwater lakes (three meters deep and one kilometre in diameter) such as Zichri and Baghdadia lakes (Richardson and Hussain, 2006).

1.2.1 *Biodiversity and conservation status of the Central Marsh*

Forty-two important bird areas (IBAs) were recorded in Iraq according to the criteria of Birdlife International, with twenty six of them located in the south of Iraq (Evans, 1994). The Central Marsh was indicated as one of the most important sites for birds in the south of Iraq (site 38 in (Evans, 1994)). In addition, the site was listed as one of the Mesopotamian wetlands of international importance (site 27 in (Scott and Evans, 1993)). The Central Marsh was surveyed seasonally (using rapid survey methods) from 2005 to 2010 as one of the Key Biodiversity Areas of Iraq (KBAs; Nature Iraq, 2017).

The CM was identified by Evans (1994) as an IBA according to the following criteria and evidence: i) criterion A1 (the site has globally threatened species): the CM has 98 – 185 breeding pairs and 1800 – 12000 of Marbled Duck (*Marmaronetta angustirostris;* Red List category VU), and 3000 breeding pairs of Basra Reed Warbler (*Acrocephalus griseldis; Red List category EN);* ii) criterion A2 (presence of restricted – range species): the CM is habitat for Basra Reed Warbler and 1500 pairs of Iraq Babbler *Turdoides altirostris*, criterion A3 (Biome – restricted species), the CM has 32-60 pairs of White-tailed Lapwing *Vanellus leucurus*, 14 pairs Spotted Sandgrouse *Pterocles senegallus*, 11 pairs Egyptian Nightjar *Caprimulgus aegyptius*, 14 pairs White-eared Bulbul *Pycnonotus leucotis*, Basra Reed Warbler, Iraq Babbler, and 6000 pairs Dead Sea Sparrow *Passer moabiticus;* iii) criterion A4i (the site holds 1% or more of the global population of a waterbird species): the CM has 98 – 185 breeding pairs and 1800 – 12000 of Marbled Duck; iv) criterion A4ii (the site holds 1% or more of the global population of a seabird or terrestrial species): the CM provides habitat for Dead Sea Sparrow; v) criterion A4iii (the site holds congregations of 20,000 waterbirds or 10,000 seabirds of one or more species): the CM has up to 74,000 water-birds.

During the KBA surveys 94 bird species were recorded, and other important fauna was mentioned such as: smooth – coated Otter *Lutrogale perspicillata maxwelli* (status of this species mentioned as unclear), Eurasian Otter *Lutra lutra*, Ruppell's Fox *Vulpes rueppellii*, jungle Cat *Felis chaus*, and the endangered soft shelled turtle *Rafetus euphraticus*. On the other hand, forty – four aquatic plant species were recorded during the same surveys and 16 terrestrial plant species. Moreover, the observed aquatic habitat was classified into 4 groups: inland running water, inland standing water, marsh vegetation, and food communities (Rubec, Alwash and Bachmann, 2009; Nature Iraq, 2017) . The threat status and pressures faced by the Central Marsh were scored as very high and very rapid in 2013 by BirdLife International (BirdLife International, 2017). The threats were as follows: natural system modification (threat level 1), and specifically dams and water management (threat level 2). In addition, Birdlife International highlighted the conservation actions taken at the site as not assessed and negligible.

1.2.2 *Protection status and management plan of the Central Marsh*

Six marshes (Haweiza marsh, Eastern Hammar marsh, Al Awdah marsh, Central marsh, Abo Zirig marsh, and Western Hammar marsh) were short-listed at the end of 2006 by the Iraqi government and Nature Iraq to be designated as protected areas after the re-flooding of the marshlands in 2003 (Alwash *et al.*, 2009). Priority was given to the Central Marsh and Abo Zirig (141, 615 ha) to be the first national park in Iraq under the name "Mesopotamian National Park" (Nature Iraq, 2006b). Aspects of environmental and socio-economic issues were considered to give the priority for both sites, and three phases were suggested to implement the project: i) a feasibility study; ii) a management plan; and iii) operational and pilot projects (Nature Iraq, 2006d). The feasibility study stage focused on park description, data analysis, and benefits provided by the park; the draft management plan suggested three scenarios for the park's future development: educational and science research assets, socio-economic assets, and touristic assets. In the third stage several pilot projects have been suggested to support the park and the local people (Nature Iraq, 2006a). The Central Marsh was chosen to be a core zone for the national park due to its central location within the marshlands system, high-level interactions between people and nature, and for its ability to be expanded in the future. In addition, the park borders have been delineated based on three criteria: territorial features of the area, socio-economic situation, and strategic view of the rehabilitation of the entire marshlands system (Alwash *et al.*, 2009).

Despite the huge planning efforts spent to finalize the national park, the project has taken a long time to be adopted by the Iraqi government. The park was declared official by the government in 2013 (Pearce, 2013). However, the management plan of the park and the pilot projects remained as drafts. Birdlife International has indicated that 95, 000 ha of the total area of the Mesopotamian national park is overlapped with IBAs, and the key action required is to develop the management plan of the site (BirdLife International, 2017). Thus, urgent action is required for updating and aiding the management plan of the national park.

1.2.3 *Socio – Economy of the Central Marsh*

The Central Marsh considered as a socio – ecological site due to the high levels of interaction between local people and nature for a thousand years (Alwash *et al.*, 2009). Chibayish City is the core of the Central Marsh and the most famous area that represents the marshlands. The current urbanisation of Chibayish city is new (Nature Iraq, 2006d). However, before becoming urban, Chibayish City contained the houses of local people (called Ma'adan), which floated on the water. The meaning of word Chibayish in Arabic is derived from the way that local people used to build their houses (the people cut reeds from the marsh and then compressed it as layers inside the water to form a small area of reed that was able to float on the water, which was then used as a foundation for further construction). Each floating house was called Chibsha (singular) in Arabic and Chibayish (plural) for the village) (Nature Iraq, 2006b). The local people of the Central Marsh relied totally on the services provided by the ecosystem in the past, where they used to cultivate rice as the main crop for food. However, the majority of their economy and food relied on water buffalos (milk and meat), fishing, and bird hunting. Thus, the local people were displaced/migrated outside the marsh after the disaster of marsh's desiccation in 1990s (Al-Ansari, Knutsson and Ali, 2012).

Water buffalo *Babalus babalus* are the most important domestic animals for the Ma'adan in the Mesopotamian Marshlands. The buffalo were introduced to the Mesopotamia in 3500 BC; however, some people believe that the buffalos were wild animals in the marshlands and then domesticated by local people (Nature Iraq, 2006a). Buffalo numbers decreased significantly in Iraq from 141,450 in 1986 to 98,700 in 1993 due to four reasons: buffalo farmers quit to search for another job in the cities, increased buffalo slaughtered during times of economic sanction on Iraq, reduced fertility, and increased incidence of buffalo diseases (Fazaa, 2007). The numbers of buffalos decreased significantly after 1993 in the marshlands due to desiccation (90% of the Ma'adan migranted from the Central Marsh north towards cities like Cibayish; Richardson and Hussain, 2006). However, a reverse migration happened after the marshlands restoration in 2003.

The numbers of water buffalos were estimated at 40,008 after the re-flooding in the marshes of Missan and Thi – Qar provinces including the Central Marsh (Abid *et al.*, 2007). The same study indicated the presence of 4,424 lactating buffalo in the marshes of Thi-Qar province, which produced 22,055 litres of milk daily (milk production of buffalo was estimated as 3-7 litre/cow/day). While, the milk production was estimated as 4-5 litre/cow/day in summer and 15 litres in winter, the price of the milk (direct from the families not from dealers) was estimated at 2,000 ID ≈ $10 USD/25kg in 2007, while the price of buffalo ranged between $417 to $2,083/head in 2007 (Fazaa, 2007). The same study indicated that water buffalo activities in the marshlands can be divided into two activities: winter and summer activities. Buffalos spend 10h-12h inside the marsh in summer to cool their bodies, because the buffalos dissipate heat poorly by sweat glands (buffalo skin has fewer sweat glands compared with cattle), hence, the buffalo rely on the marsh's plants for food in summer, while they eat mulch a lot in winter, because they do not enter the water and rely on the owners to feed them a mixture of plants and fodder during the day (the fodder is mixed corn, wheat, bran and other grains; Abid *et al.*, 2007). Due to the bad security situation in the middle of Iraq and restoration of the marshlands, the reverse migration of buffalo farmers from cities to the marsh continued to increase, especially in the Central Marsh even after declaring the CM as a national park (Nature Iraq, 2017). Increasing numbers of water buffalo could have a positive impact on the GDP of the CM's local people. However, due to current environmental challenges that have resulted from water scarcity, the buffalo and Ma'adan could be faced with the prospect of migration out of the CM once again. Thus, there is an urgent need to evaluate the situation of water buffalo in the Central Marsh after declaring the site as a protected area, and to estimate the economic value of water buffalo and its milk production in the CM.

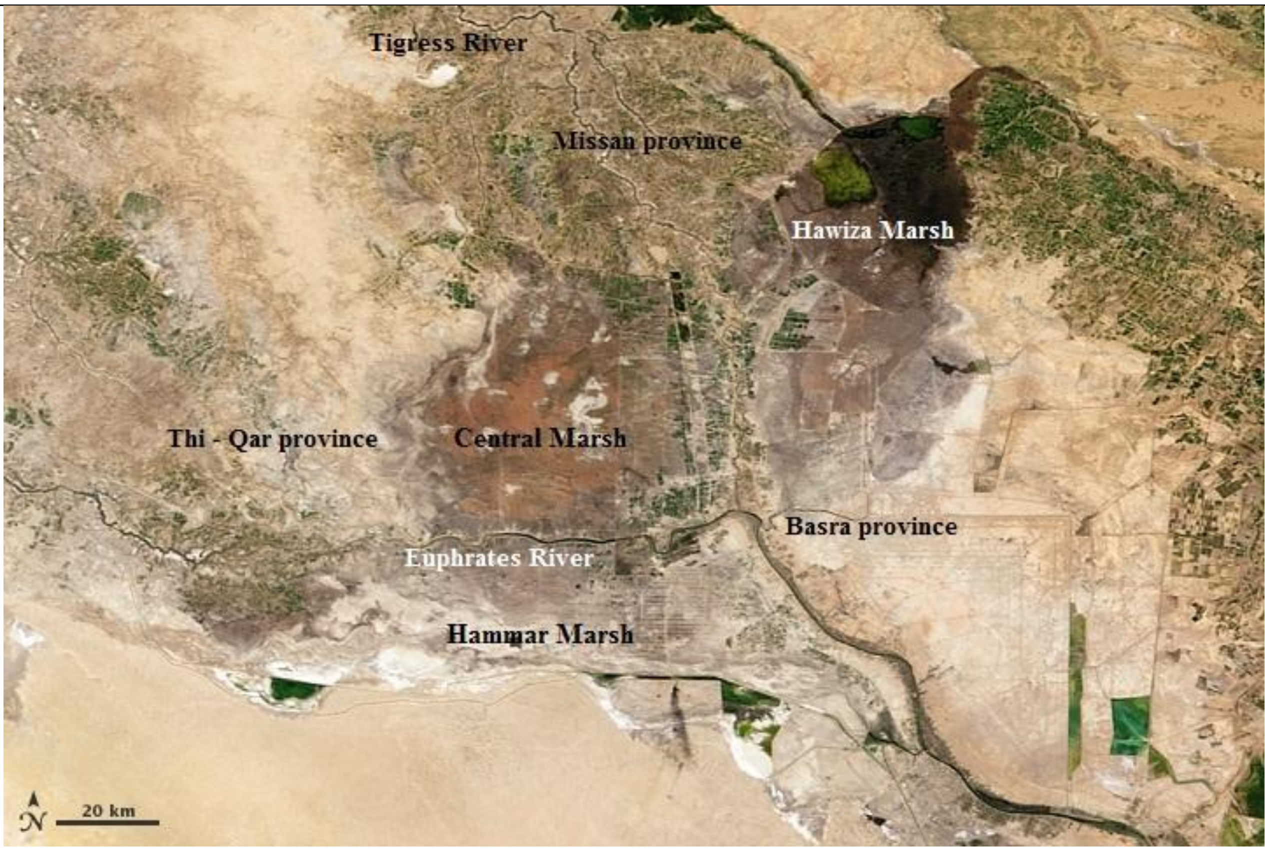
1.2.4 *Environmental challenges of the Central Marsh*

The Central Marsh has faced the same problems as all the other Mesopotamian Marshlands in the 20th century. The re-flooding efforts spent after 2003 failed to restore the Central Marsh to 100% of its historical size due to water scarcity in both Tigress and Euphrates Rivers (Nature Iraq, 2006b; Al-Maarofi *et al.*, 2013; Al-Maarofi, 2015). In addition, the natural hydrological system of the CM has changed dramatically. Historically, most water entering the CM came from the Tigress River in the north side of the marsh and met water from the Euphrates River in the south of the CM. However, due to water scarcity in the Tigress River this natural scenario cannot work anymore.

The Tigress River inside Iraq used to receive 20.9 km^3/year of water from Turkey, however, that amount decreased by half when Ilisu dam was constructed and is likely to cause negative impact on 696,103 ha of agricultural land and, will sequentially deplete the marsh's water (Al-Ansari and Knutsson, 2011). The Central Marsh received 11, 39 and 16 m^3/s from the branches of Tigress Rivers Al Areed, Butera, and Al Majer Al Kabeer respectively in October 2005, however, it was difficult under the circumstances of water shortage in the Tigress River to continue providing water to the Central Marsh. Thus, the government and New Eden team decided to construct water regulators from both north and south sides of the CM to keep it restored in 2006 (one regulator from the North on Tigress River and 9 regulators from the south on Euphrates River, and two regulators inside Abo Zirig Marsh; Nature Iraq, 2006a). As a result, the water flow of the CM was converted from natural flow to artificial controlled flow. Despite the high levels of engineering efforts, the problem of water scarcity worsened further in 2008 and became a severe problem, which made the government significantly decrease the amount of water provided from Tigress River to the Central Marsh and made the site relying totally on the water from the Euphrates River.

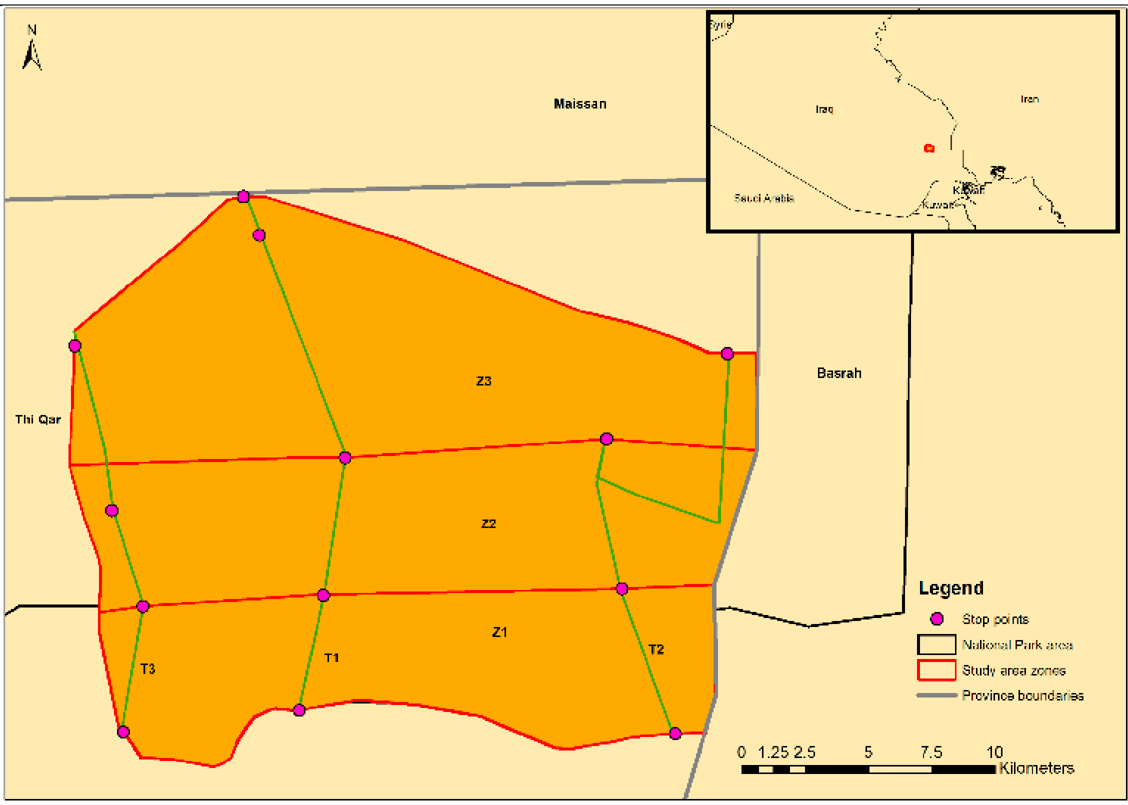
Despite the government considering the action of flooding the Central Marsh by using water from the Euphrates River as a good solution, it has drawbacks that could change the ecology and the ecosystem services of the site. The Euphrates River (2,781 km long) crosses Chibayish City from the west to the east and is located in the southern part of the CM. The source of the river's water is totally from outside Iraq with no tributaries inside Iraq (12% from Syria and 80% from Turkey; Nature Iraq, 2006a). The River passes 5 provinces inside Iraq (Anbar in the west of the country, Najaf, Al Qadisia (Diwaniya), Samawa, and Thi – Qar), before meeting the Tigress River at the 6th province (Basrah) in the south of the country (the last city that is passed by Euphrates River in Thi-Qar province is Chibayish City, which is our area of study). The estimated annual average of Euphrates flow is 30 $km^{3/}$year (951m^3/sec) before 1990, while it dropped to 4.4 km^3 (230m^3), a 90% reduction in 2011, which converted 50% of agricultural areas to desert, negatively affecting water quality at national level (Al-Ansari and Knutsson, 2011) and regional level (the Gulf) (Al-Yamani *et al.*, 2007). In addition, water depletion in the river affected the marshlands area that needs 2 km^3/year (64 m^3/sec) to be maintained (Richardson and Hussain, 2006).

As a reaction to the bad situation that faced the Euphrates River and its potential effects on the CM, the government and local authority decided to construct a soil embankment on the Euphrates River at the border between Chibayish City in Thi-Qar province and Modina City in Basra province to use water of Euphrates River to inundate the Central Marsh (Nature Iraq, 2006a; Rubec, Alwash and Bachmann, 2009). Despite the argument between Basrah and Thi-Qar provinces regarding constructing the soil embankment the project was implemented in 2011. However, the impact of the soil embankment on the CM and making the site the final destination for the waters of Euphrates River in the scenario of water scarcity in the river is unknown. Thus, there is a need to evaluate the CM under its current unique challenges and problems.



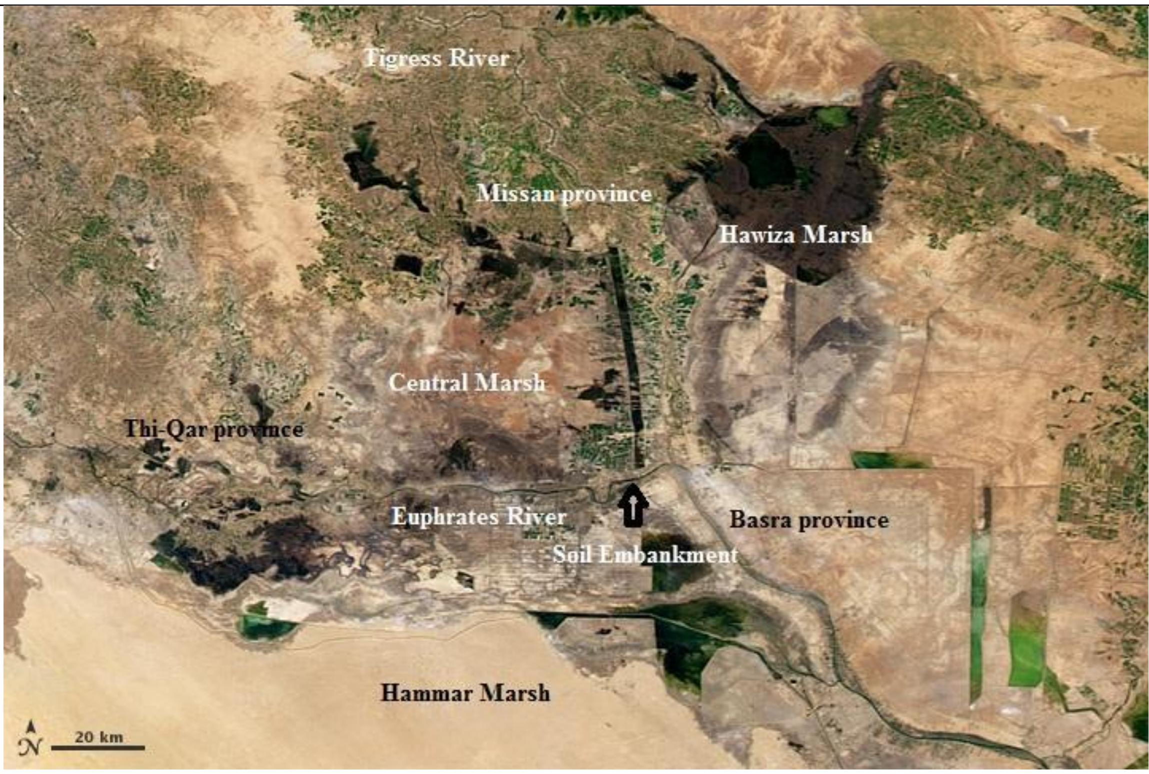
a. Mesopotamian Marshlands: drought in 2002

b. Mesopotamian Marshlands: drought in 2002

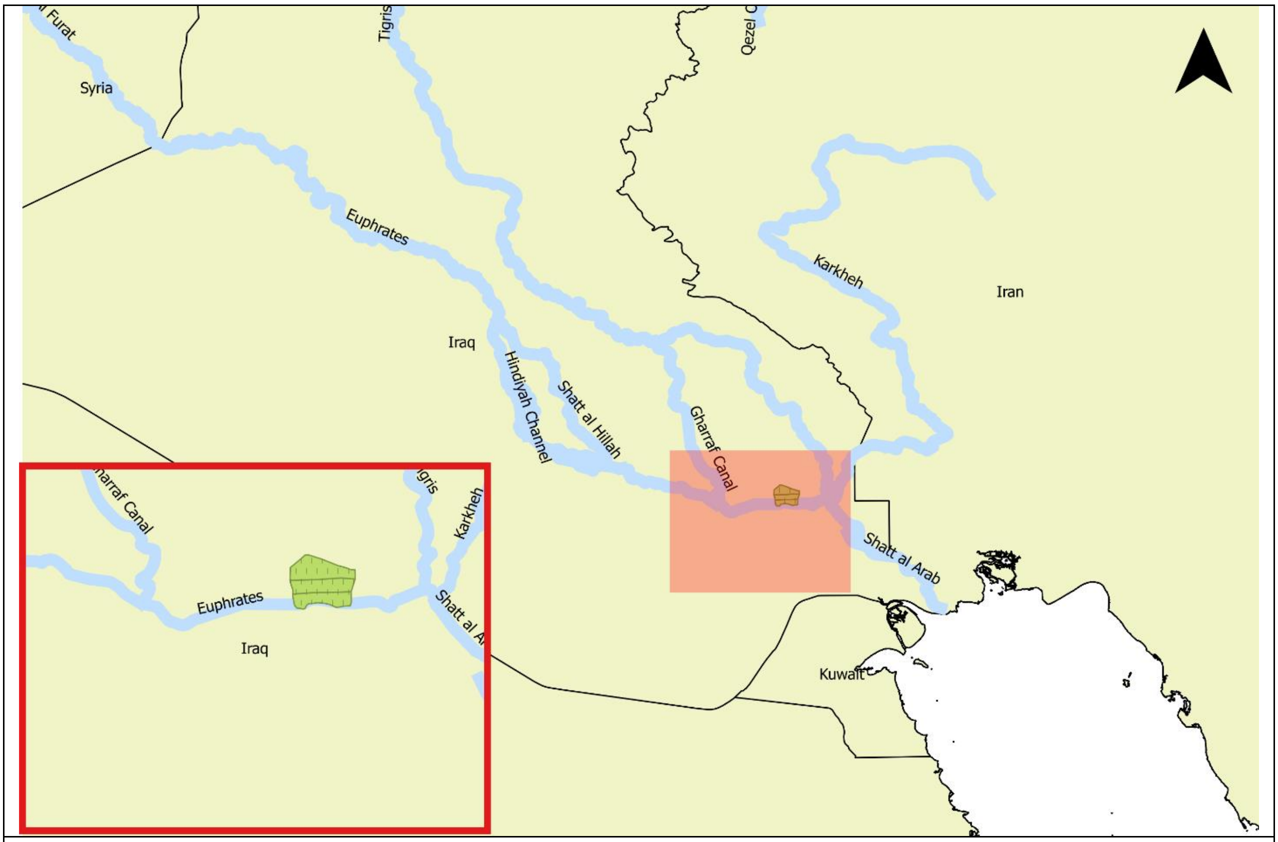


c. Central Marsh: area of study

d. Mesopotamian Marshlands: Flooding in 2008



e. Mesopotamian Marshlands: Drought in 2010



f. Central Marsh within Iraq and regional rivers

Figure 1.1. Figures 1.1 a, b, d, and e show satellite images on the Mesopotamian Marshlands in years: 2002, 2005, 2008, and 2010 respectively (Lindsey, 2017). Key for satellite images: yellow = sand, green = vegetation, dark blue = water. Note the differences between years with flooding and drought. Figure 1.1c shows an illustration of the study area for the PhD and Figure 1.1f shows the location of the study area within the wider landscape of Iraq.

1.2.5 Ecosystem management and services of the Central Marsh

Ecosystem definitions have developed throughout time. Maltby (1999) summarised the definitions of ecosystem starting from 1807 when Humboldt wrote that “in the great chain of causes and effects nothing and no activity should be regarded in isolation”, and then in Tansley (1935) defined the ecosystem formally as “a unit of vegetation which … includes not only the plants of which it is composed but the animals habitually associated with them, and also all the physical and chemical components of the immediate environment, or habitat which together form a recognisable self-contained entity” , After that Fosberg (1963) described the ecosystem as a “functioning, interacting system composed of one or more living organisms and their effective environment, both physical and biological. The description of an ecosystem may include its spatial relations, inventories of its physical features, its habitat and ecological niches, its organisms and its basic reserves of energy and matter, the nature of its income of matter, and energy and behaviour or trend of its entropy levels". Finally, a term of eco - complex was added by Polunin and Worthington (1990) in 1990 to be used for larger and less – integrated systems (such as lakes, rivers, islands, and forests) that contain several ecosystems.

Ecosystems can provide services to benefit people such as: food production, clean water, and climate regulation and these benefits can be defined as ecosystem services (Millenium Ecosystem Assessment, 2005). Pressures on ecosystems have increased significantly in the last 50 years, which has made huge changes in the ecosystem services provided (Millennium Ecosystem Assessment, 2007). The International Convention for Biological Diversity (CBD) has addressed loss of biodiversity and adopted 20 targets to conserve biodiversity including two targets that focused on ecosystem services (target 14: "by 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable", and target 15: "by 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification"). Increasing human global populations and changes in land use were the main reasons for changes in ecosystems (ICSU-UNESCO-UNU, 2008). In addition, decreasing human resilience (e.g. removing response diversity and removing whole functional groups of species) and increasing pressures such as: impact of pollution and waste, and climate change are another driver of ecosystem change and makes them more vulnerable (Maltby, 1999; Folke *et al.*, 2004). Global ecosystem services were estimated at $125 trillion/year in 2011, and the loss and damage to ecosystems were estimated $4.3 - $20.2 from 1997 to 2011 (Costanza *et al.*, 2014).

Ecosystem management is defined as manipulation of chemical, physical, and biological processes that link organisms with their abiotic environment and human regulation actions to make a desired ecosystem that could include: adjusting the chemical conditions by controlling pollution, physical parameters regulation; controlling biological interrelationships; controlling human use for the ecosystem and making an intervening in cultural, social, and economic processes; or could be defined as “a human activity that affects both ecosystems as traditionally defined as well as larger spatial units such as eco-complexes” (Maltby, 1999). Wetlands provides huge services to support sustainable human well-being, and the value of ecosystem services that are provided by one hectare of wetlands was estimated at $30,000/ha (Sukhdev *et al.*, 2010). Interactions between human (social) and nature is essential to support sustainable human well-being (Costanza *et al.*, 2014). The Central Marsh in the southern of Iraq is an ideal example of long term interactions between local people and nature. Ecosystem services of the CM are public goods and free for everyone without any control from the government or local authority. Despite the huge benefit that is gained from the CM there is no adequate information regarding the value of the site ecosystem services, which could be threatened due to the current environmental problems that are facing the CM.

1.3 The global threat of Climate Change

Significant increases of greenhouse gases (GHGs) in the atmosphere since the industrial revolution have left the Earth highly exposed to climate change (Houghton *et al.*, 2001). CO_2 concentrations in the atmosphere fluctuated between 150-250 ppm at equilibrium before the industrial revolution, while after the industrial revolution it has significantly increased. As of 2014, there had been an increase of 40% to 399 ppm , which has resulted in an almost 0.8°C increase in the mean global temperature (Stocker, 2014) and is predicted to cause extreme and unexpected environmental changes in the future. Ninety percent of scientists have confirmed the existence of anthropogenic climate change (Cook *et al.*, 2016).

The IPCC has highlighted five reasons for concern regarding climate change in its 5th report: i) unique and threatened systems: there is high confidence that some cultures and ecosystems are currently at risk of climate change and the number of threatened ecosystems will increase under the 1°C warming; ii) extreme weather events: risks are high with 1°C warming (medium confidence), and will increase with the further warming scenario that is associated with extreme events such as: extreme heat; iii) distribution of impacts: people and regions have different distributed risks of climate change; the risk is currently moderate and is expected to be higher in the scenario of 2°C warming; iv) global aggregate impacts: loss of biodiversity and ecosystems' goods and services at high risk in the scenario of 3°C warming (high confidence); v) large-scale singular events: risk of irreversible change of some ecological systems are moderate between 0 and 2°C warming (e.g. coral reefs and arctic ecosystems are already at irreversible risk and undergoing regime shifts). Thus, the ability of ecosystems to convey fundamental services to society is already under stress and the problem will be more complicated in the future under climate change impacts (Mooney *et al.*, 2009).

We have passed some planetary boundaries (e.g. biodiversity loss) and are currently approaching what has been called the 6th extinction phase of biodiversity on Earth (Barnosky *et al.*, 2011). For example, natural rates of extinction are one species/million species/year and the boundary rate is 10 species/million species/year, while the current rate is 10 – 100x/million species/year (Steffen *et al.*, 2011). Recently, direct impacts of climate change have been defined as a strong dominant cause of biodiversity loss on the local and global levels in this century (Thomas *et al.*, 2004; Stocker, 2014) . Almost 20–30% of fauna and flora species are at high risk of extinction due to the rising of global mean temperatures 2–3°C above pre-industrial levels (Fischlin *et al.*, 2007; IPCC, 2007). Increasing human populations will themselves be vulnerable to climate change, and human adaptation responses are likely to be an additional indirect negative impact on biodiversity and natural ecosystems (Pacifici *et al.*, 2015). Consensus between countries under the umbrella of UNFCCC suggests that temperature rises should be limited well below 2°C compared with global mean temperatures before the industrial revolution in order to avoid catastrophe and risks of climate change. In addition, they strongly agree that such a change requires huge efforts and urgent actions from all countries to undertake a dramatic shift towards resilience thinking and sustainable development (Dellink, Briner and Clapp, 2011; Kartha and Erickson, 2011).

Although Iraq is one of the developing countries and classified as non-annex one in the convention of climate change UFCCC, the country is considered one of the richest countries in the Middle East due to its large reserves of oil and natural gas (Ministry of Health and Environment, 2016). More than 90% of Iraq's national budget, economy, future vision, development plans, and strategies rely on oil and fossil fuels; oil production was 2.7 million barrels in 2011 and is projected to be 6 million barrels in 2017 and 2020, and Iraq's total national budget was $82.6 billion in 2011 and its oil income was $80 billion (Iraqi Extractive Industries Transparency Initiative, 2013). In addition, the country is still using old machines, plants, and equipment in the industry and electricity sectors (Al-Khatteeb and Istepanian, 2015), which is considered to be in opposition to the new global vision towards sustainable development and low CO_2 emissions.

Rapid population growth in Iraq (population of Iraq was 3 million, 19 million and 33 million in 1920, 1997, and 2014 respectively (Central Statistical Organisation Iraq, 2017) has added more pressure on natural resources and increased energy and fresh water demands (Ministry of Environment, 2014). This problem, along with the current economic vision of Iraq, wars and political conflict makes the country highly exposed and vulnerable to climate change (developing countries are expected to face more effects of climate change than developed countries (e.g. the relative percentage changes to GPD from climate change is greater in developing countries than in developed countries; IPCC, 2001). Highlighting the urgent need to adopt a new way of resilient national thinking, a new vision, new strategies and plans is extremely important in order to take the global sustainable vision in consideration and help the country to have a gradual shift towards a decarbonised economy and an increased national adaptation ability.

Iraq is already facing a problem of water scarcity that is a result of conflict (King, 2015), water control by neighbour countries (Al-Ansari and Knutsson, 2011), a lack of advanced national water management, and an old national agriculture irrigation system (UNDP Iraq, 2014). A 16% shortage in water resources was indicated in comparison with actual country demand between 2000 and 2009. Projected water shortages of 37% and 51% have been mentioned in World Bank studies from 2011 and in national water strategies such as SWLRI 2014, but despite this, there have been no clear mention and projections to the additional impact of climate change on water resources. Natural ecosystems in Iraq are highly threatened due to scarcity of freshwater (Ministry of Environment, 2014). 220 natural ecosystems and key biodiversity areas were recorded and surveyed from 2005 to 2010 (Nature Iraq, 2017). As a result, the Mesopotamian marshlands in southern of Iraq were indicated as highly important wetlands and the most threatened ecosystems to water scarcity.

Despite the threats to the marshlands that are indicated in previous literature, there is lack of information on the impact of climate change and an evaluation of vulnerability of the marshlands and the way of future ecosystem adaptation to climate change. The Central Marsh is an ideal example of interactions between people and nature, and the site provides huge services to the local people and wildlife, hence, Iraq could lose the huge economic and ecological benefits that are gained from such a productive site under the impact of climate change. In addition, the CM could be very good case study for future studies that aim to address impact of climate change on natural systems and other marshes in Iraq.

1.3.1 *Exposure of ecosystems to climate change*

Exposure to climate change is the degree of stress that results from climate variability such as changes in mean temperatures, levels of precipitation, sea level, and frequency of extreme events (IPCC, 2001). In addition, an inventory of elements in an area where hazards may occur can be referred to as exposure (Cardona *et al.*, 2012) and changes in habitat suitability indices also can be classified as exposure (Dawson *et al.*, 2011). Ecological responses to climate variability are already recognised at present (Walther *et al.*, 2002). However, exposure alone is not sufficient to define an area as at risk without evaluating vulnerability (e.g. having sufficient modified building structures when living in a floodplain will decrease potential loss even if the area under exposure), conversely, in order to be vulnerable to an extreme event the area should be exposed in advance (Cardona *et al.*, 2012).

Effects of climate change will not be uniform or sequential and exposure of countries to climate change will be different. Previous studies indicated changes of temperature and rainfall in Iraq between past and present while no clear projection is available on the country level. Mean temperature has changed by +1.5-2.5°C in the period between 1941 – 2009 (Ministry of Health and Environment, 2016), and +5°C in the period 1960 to 2007 (Awadh and Ahmad, 2012). The same studies indicated a reduction in annual mean rainfall from 550mm to 200 in the North and from 250 to 75mm in the South but remained steady in the West for the same period. Despite, the exposure of the country to increases in temperature and decreases in rainfall there is no specific focused studies on exposure of the marshlands to climate change. The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, economic, social, and cultural assets in the marshlands could make them adversely affected by climate change. Thus, evaluating exposure of the marshlands to climate change is considered an important and urgent step.

1.3.2 *Vulnerability of ecosystems to climate change*

Vulnerability has become the centre of focus in the climate change field (Stocker, 2014). It is the degree of potential harm that is likely to affect human and environmental systems due to global change including climate change (Lardy *et al.*, 2012). Vulnerability could be defined as *"the degree to which a system is susceptible to, or unable to cope with, adverse effect of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity"*, while sensitivity has a different definition: *"sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate change – related stimuli. Climate-related stimuli encompass all elements of climate change, including mean climate characteristics, climate variability, and the frequency and magnitude of extremes. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise)"* (IPCC, 2001).

Vulnerability and exposure of socio-ecological systems and societies to climate change depend on several factors such as: economic factors, social, cultural, institutional, and governance. In addition, unmanaged ecosystems can add stress that could raise the vulnerability of the systems (Patwardhan, Semenov and Schnieder, 2007). However, vulnerability differs across regions and populations within regions (different regions have varied characteristics, resources, and pressures; some regions are defined as vulnerable due to its exposure to climate change hazards or weakness of its adaptive capacity such as less developed countries; Stocker, 2014); the greater exposure or sensitivity of an ecosystem, the greater vulnerability, while the greater adaptive capacity of systems the less vulnerability (IPCC, 2001). Despite the expected changes that could happen due to climate change, anticipating responses of ecosystems to changes is a difficult process (e.g. using past observations in adequate models to assess particular ecosystems cannot guarantee the same future relationships of the system, hence, assessing vulnerability of ecosystems to climate change is considered a challenging task (Luedeling, Muthuri and Kindt, 2013), and fully convincing methodology to evaluate quantitative vulnerability does not exist (IPCC, 2001).

On the species level, there is no ideal definition to vulnerability. However, function of intrinsic and extrinsic factors could be the most generally accepted definition of species vulnerability (Pacifici *et al.*, 2015). Many species and populations are already vulnerable to climate change and habitat degradation. Plant and animal species extinction has increased significantly (11%, 25%, and 34% of the world's birds, mammals, and fish species respectively are vulnerable), and without appropriate management plans, there is high confidence that the conservation status of species will be changed (Stocker, 2014). The scale of ecosystems' exposure and vulnerability to climate change has increased significantly, thus, prioritizing the most vulnerable systems and species have become an urgent action and a focused area by policy makers at the global and national levels (vulnerability is important, because it is a bridge between climate change impacts and adaptation) (Cardona *et al.*, 2012).

Direct measurements of vulnerability is a challenge; thus, it is used to describe situations of climate change impact in theory and situations that derived from models (Luedeling, Muthuri and Kindt, 2013). Asking "what" questions (what/who is vulnerable? what is vulnerability? and vulnerable to what?) has been suggested as a major theme of climate change research that reflecting the UNFCCC concern regarding the most vulnerable people, and as appropriate way to identify different definitions and methods of vulnerability (Patwardhan, Semenov and Schnieder, 2007). Although vulnerability to climate change has become important field, a small percentage of the climate change literature has focused on it due to a limitation in methodologies and difficulties of assessing vulnerability, while it seems evaluation of exposure is easier (Lardy *et al.*, 2012). For example, in a review of 410 scientific publications only 10% presented a concept assessment of vulnerability, while 52% focused on temperature and rain precipitation. Methods used in the reviewed studies were: experts knowledge 29%, modelling

27%, statistical 27%, observation 5%, and experimentation 2% (Luedeling, Muthuri and Kindt, 2013).

There are 4 main approaches for assessment of species' vulnerability and were highlighted in Pacifici *et al.* (2015); correlative, mechanistic, trait-based, and combined. Expert explanation and assessment could be an additional approach that could provide an estimated evaluation for ecosystems and species vulnerability. Despite all efforts spent to evaluate assessment of ecosystem and species vulnerability few approaches have provided satisfactory cover for the relevant aspects; exposure, sensitivity, and adaptive capacity (Luedeling, Muthuri and Kindt, 2013). Biodiversity and habitat lost is a serious concern due to climate change especially in developing countries. Huge number of people are highly dependent on ecosystem services in the developing world. Thus, evaluating vulnerability of ecosystems at the site and species levels and prioritizing the most important sites are urgent actions. Local people of the Central Marsh (Ma'adan) and high numbers of animal species are highly dependent on the habitat of the site. However, the site currently faces lots of environmental problems, and the climate change could be an additional stressor. Therefore, evaluation of the site vulnerability to climate change may aid and enhance the site management plan, and add the site on the national priority list of ecosystems.

1.3.3 *Adaptation of ecosystems to climate change*

The adaptive capacity of natural ecosystems and humans to adjust and cope with changes that result from impact of climate change is termed 'adaptation' (IPCC, 2001). There is a consensus by scientists that climate change is a result of anthropogenic activities (Cook *et al.*, 2016) that could end the 10,000 years of Earth's climate stabilization during the Holocene era and advent a new geological period called the Anthropocene epoch (Steffen *et al.*, 2011). According to the IPCC 4th and 5th reports, a fast transformation from using fossil fuels to clean mechanisms and renewable energy is urgently needed to mitigate CO_2

emissions, which is considered the first important step to increase the planet's adaptation to climate change (Fischlin *et al.*, 2007; Stocker, 2014).

The IPCC vision supported the ultimate goal of the United Nation Framework Convention on Climate Change (UNFCCC) "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt to climate change, ensure that food production is not threatened and enable economic development to proceed in a sustainable manner." (UN, 1992). Adaptation processes can reduce adverse impacts of climate change, however, cannot prevent all damages (Füssel, 2007). The extreme events, variability, and rate of changes that results from climate change, not the changes that occurs in the average of climate conditions, all are the features of addressing vulnerability and adaptation (Luedeling, Muthuri and Kindt, 2013).

Human and natural systems have some degree of autonomous adaptation and planned adaptation strategies can support such adaptation. Adaptation strategies are very important at all scales to complement CO_2 mitigation plans (IPCC, 2001). Failure or delay in the adaptation process against climate change will drive the Earth further into the Anthropocene and that could be irreversible, thus, there is an urgent need to adopt effective planetary stewardship (Steffen *et al.*, 2011). Although climate change is a global phenomenon, mitigation and adaptation should be urgently taken at the national level (Stocker, 2014). Ecosystem services and biodiversity in ecosystem-based approaches to adaptation are used as part of the overall adaptation strategy to help people adapt to the adverse effects of climate change, and that could include sustainable management, conservation, and restoration of ecosystems (UNEP, 2010). In addition, adaptation and sustainable development are linked together (Julius *et al.*, 2008).

Although Iraq is considered one of the most vulnerable countries in the Middle East to climate change, there is no adaptation strategy available on the national level, hence, choosing the Mesopotamian Marshlands as a case study could support future national adaptation plans including natural ecosystems.

1.4 Aims of the study

The Central Marsh, site of the first national park in Iraq and a UNESCO World Heritage Site listed in 2016, comprises a unique and highly important location noted both for sustaining a complex and biodiverse ecosystem of international significance as well as being the site of several early human civilizations. The marshes still sustain a local community who rely on the wetlands and their ecosystems. This research seeks to examine how the global phenomenon of climate change is likely to impact the Mesopotamian Marshes, in particular, in relation to the animal ecology in the area, and to develop an adaptation plan to deal with the effects and mitigate any negative impacts. The ultimate aim is to answer the question: is the Central Marsh (as a case study) exposed and vulnerable to climate change? This will allow us to help develop the ideal adaptation plan of the site to climate change. The thesis is divided into five main chapters with a focus on the main current problem, which is water scarcity and potential future problems that could result from climate change. The first two chapters focus on the status of key animal species in the Central Marsh (terrestrial birds and aquatic soft-shelled turtle), the third chapter focuses on providing a valuation of the CM’s ecosystem services, the fourth chapter provides baseline data on water quality and, and the last chapter provides an evaluation of the site’s exposure, vulnerability, and adaptability to climate change and suggests resilience recommendations.

Individual aims for each chapter:

1. Birds:
    - i. To provide an inventory of bird species occurring in the CM.
    - ii. To investigate the spatial and temporal patterns of bird abundance and diversity across the CM.
    - iii. To describe bird assemblages within different areas of the CM.

2. Soft-shelled turtle *Rafetus euphraticus*:
   i. To survey the CM for this species and to record some basic reproductive parameters
   ii. To calculate population densities of the species with the CM by using transect line methodology, and recording turtle individuals outside water
3. Ecosystem services:
   i. To place a value on the CM's main ecosystem services at the site level.
4. Water quality:
   i. To evaluate the current role of the CM in cleaning water from the Euphrates River under the current unique circumstances.
5. Climate Change:
   i. To evaluate the exposure of the CM to climate change by mapping past changes in air temperature and rainfall both for the marshlands and in other regions in Iraq.
   ii. To predict the impact of climate change on socio-economic and biodiversity receptors (birds as key species) in the CM.
   iii. To make policy suggestions for future national resilience planning to tackle climate change in Iraq based on (i) and (ii) as a case study.

Chapter 2. Distributions and community composition of birds in Iraq's Central Marsh

Summary

The Central Marsh (CM) in southern Iraq is known to provide important habitats for both resident and migrant birds. The CM has been used extensively by humans, in part due to its high levels of productivity and biodiversity. It was drained in the 1990s by the government and re-flooded and restored in 2003. Recent brief surveys of the CM from 2005 – 2010 recorded 94 bird species. Our study combined transects and point counts in detailed monthly surveys from October 2013 to June 2014 in the CM. We found a total of 125 bird species in the CM across all surveys, with 31 species recorded for the first time in the CM and 11 species categorised as red listed by the IUCN. Fourteen species were confirmed breeding in the CM. Cluster analysis using NMDS ordination showed that the study area can be divided into three main clusters of bird assemblages which are presented here. We provide management recommendations based on our findings.

2.1 Introduction

Restoration of wetlands also has a long history with a range of factors identified as likely to contribute to 'success' however that is judged (Zedler, 2000, 2007). Here the 'value' of the study site is focussed on the birds that the site supports. The Iraqi Central Marsh (CM) is a globally important open water and freshwater marsh (Richardson and Hussain, 2006) located between three provinces (Missan: 31°10'N, 47°05E; Thi-Qar: 30°50'N to 31°30'N; and Basra: 46°45'E to 46°25'E) in the south of Iraq (Rubec, Alwash and Bachmann, 2009). The CM is almost 300,000 ha in area and is part of a larger marshland complex (Evans, 1994). The CM has always been used extensively by humans, in part due to its high levels of productivity and biodiversity (Nature Iraq, 2017). The CM has long been known to provide important permanent habitat for large number of birds and is part of a flyway for thousands more migrating between Siberia and Africa (Maltby, 1994; Evans, 2002). Eighty bird species were found in the CM in the last complete census in the 1970s (Evans, 2002) and the area was identified as one of 42 Iraqi Important Bird and biodiversity Areas (IBAs; Evans, 1994). Despite its importance for both people and wildlife, the CM was totally drained in the 1990s by the government, which caused huge levels of biodiversity loss and the disappearance of nearly all bird species from the area (Alwash *et al.*, 2009). The motivation for this drainage is not clear, with some sources stating political motivation (Richardson and Hussain, 2006) and others agricultural expansion, which had already begun in the 1970s (Spencer, 1982).

Parts of the CM were re-flooded and restored in 2003 using the River Euphrates water to feed the CM directly, resulting in a huge reverse migration of both local people and bird species (Richardson *et al.*, 2005; Salim, Porter and Rubec, 2009). Concomitantly, there was a change in governmental attitudes and NGOs toward wildlife and the value of birds, especially regarding the maintenance of healthy ecosystem functioning (Nature Iraq, 2006a). Reflecting this change, 141,615 ha (47%) of the CM was declared as the country's first national park (NP) in 2013 (Mesopotamian National Park or MNP (Pearce, 2013; Ministry of Environment, 2014) and the CM was identified as one of 82 Iraqi Key Biodiversity Areas (KBAs), based largely on bird data collected between 2005 and 2008 (Rubec, Alwash and Bachmann, 2009). While the difficult political situation in Iraq made it impossible to conduct bird surveys between 1980 and 2003 (Richardson and Hussain, 2006), the KBA assessment showed that bird species in the CM have begun to recover to pre-drainage levels (94 species recorded; Maltby, 1994). However, many of these surveys were rapid (visiting the area for one day in the season) (seasonal surveys were conducted between 2005 – 2010 by Nature Iraq (NI) and the Iraqi Ministry of Environment) and therefore need updating to better understand the conservation statuses of CM birds. Furthermore, the KBA assessment did not explicitly examine the distributions or habitat associations of birds within the CM, treating the whole area as one conservation unit (Salim, Porter and Rubec, 2009; Nature Iraq, 2017). Treating the whole of the CM in this way could hinder attempts to restore the CM's bird populations, as many of the significant threats that face birds in the CM are not distributed equally in space. Here we present data from surveys across a nine-month period in 2013-2014.

Our study had three objectives: (i) to provide an inventory of bird species occurring in the CM; (ii) to investigate the spatial and temporal patterns of bird abundance and diversity across the CM; (iii) to describe bird assemblages within different areas of the CM. We use our findings to suggest management actions in the CM to benefit birds.

2.2 Materials and Methods

2.2.1 *Study site and sampling protocol*

Three longitudinal water transects (each 30 km in length) were chosen inside the CM to identify and count birds in the marsh from both sides of transects (Sutherland, 2006). These three transects ran approximately north-south and followed existing water courses, thus causing only minor disturbance to habitats whilst surveying (Figure 2.1). These transects were considered to be representative of the entire marshlands area given the logistic difficulties of surveying within the CM. The area has historically been supplied with water from the north by the Tigress River. The Euphrates River crosses Chibayish city from the West to the East towards Modina city in Basra province (Pearce, 2013). The Euphrates River has been closed using soil embankments between Chibayish city and Modina city due to the scarcity of water in the river. Therefore, all water coming from the West of Iraq in the Euphrates River now goes directly to the CM.

To aid management, we sub-divided the study area into three zones. We did this based on the dominant type of vegetation and similarities in the type of human activity that occurred in each zone (e.g. fishing, reed-cutting and the intensity of water buffalo used for distributing water buffalo milk). This classification was made by visual inspection of the CM and was descriptive only (based on qualitative impressions made during the survey work). Zone one started from the south in the Euphrates River and crossed Chibayish City, with zones two and three extending north inside the national park (Figure 2.1). Zone one had the most human activity, grazing by water buffalo, and dominance of the plant species *Typha domingensis*. Zone two had intermediary levels of human activity and water buffalo grazing with *Typha domingensis* and *Phragmites australis* the dominant plant species, and zone three had the least amount of human activity and grazing with *Phragmites australis* the dominant plant species.

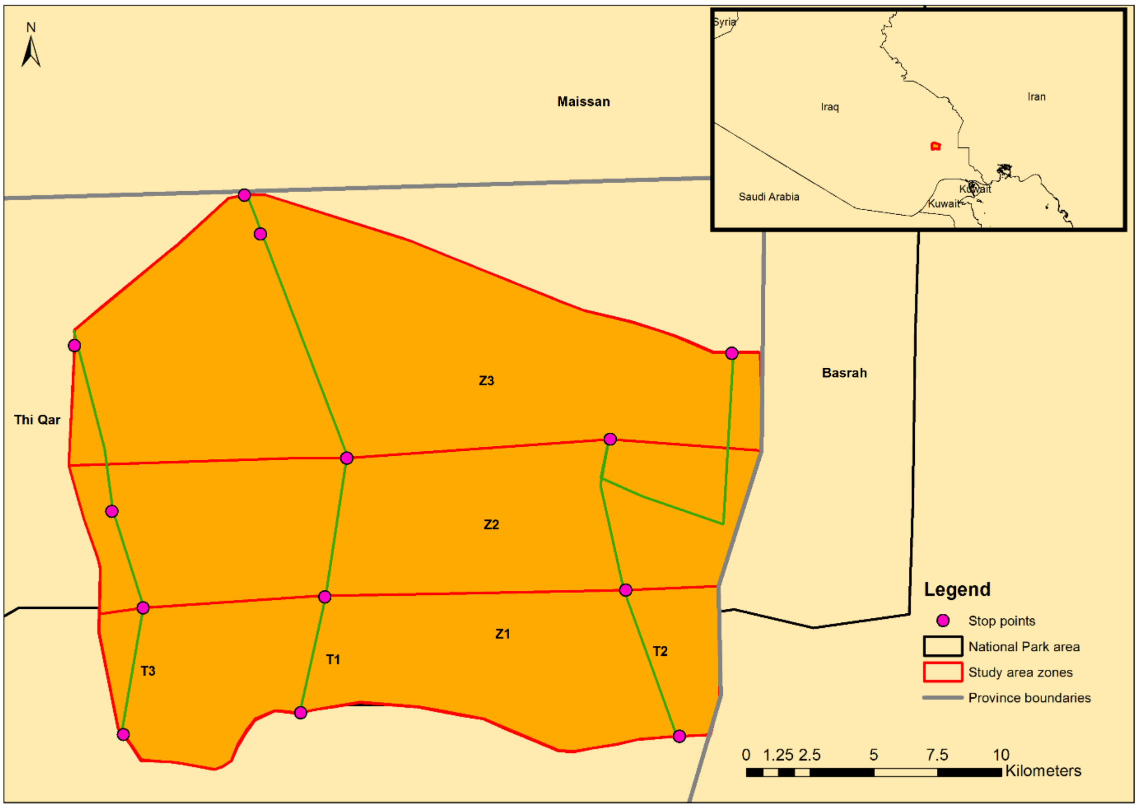


Figure 2. 1. Area of study in the CM showing locations of transect surveys (T1: transect 1, T2: transect 2, and T3: transect 3) and the location of the CM within the Middle East within the overview map (as shown in orange).

Nine surveys were carried out in the CM from October 2013 to June 2014 (for exact dates see Appendix 2). A motor canoe was for transport, with surveys started from the riverside in the south of the national park and finished in the north. Three days were spent in the area for each survey (one day/transect), and six – eight hours per day were spent moving along each transect. All field observations were conducted by the same observer and were started from the river in zone one in the morning and finished in the afternoon at the end of zone three (05:30 – 12:30/13:30 in the summer, and 07:00 – 14:00/15:00 in the winter). The stop points (point counts) are shown in Figure 2.1; time spent at each stop was 30 - 40 minutes (the survey included water and sediment sampling, therefore almost 15-20 minutes were spent for bird records in each point). Our chosen survey time for bird counts was designed to maximise our chances of detecting as many difficult to detect species as possible, while minimising our chances of double-counting. Additionally, our sampling design was constrained by safety considerations and logistical difficulties, which although making it impossible to conduct sampling in zone three in the morning, reduced our risk of double-counting further. A Canon 7D camera with Sigma lens 135 x 400 and Canon lens 100 x 400 and 8 x 42 binoculars were used to observe and count birds in the CM. No observations and counts were undertaken on the way back, apart from for new species that were not recorded in the main survey. A Garmin GPS device was used to map the three transects digitally. We used official data from the Iraqi Ministry of Water Resources - Chibayish branch to record the monthly water level in the Euphrates River during the survey period.

2.2.2 Analysis of species richness and abundance and community composition

To investigate the role of management zone, month (coded as Julian day), and transect in species richness and abundance, we used general linear models with a Gaussian error structure as our models with a Poisson, quasi-Poisson, and negative binomial error structure were severely over dispersed. To produce acceptable model residual plots, species abundance was square-root transformed but species richness was left untransformed. For each dependent variable, we constructed a full model and used a multimodel inference approach to define the relative importance of each independent variable, as recommended by Burnham and Anderson (2002) and Grueber et al. (2011). We used the package “MuMIn” (Bartoń, 2016) to produce all possible candidate models, which were ranked by AICc. We then used model averaging across the full set of candidate models to produce parameter estimates and measures of the relative importance of each parameter (Burnham, Anderson and Burnham, 2002).

Nonmetric Multidimensional Scaling (NMDS) ordination was conducted using the FactoMine R package (Lê, Josse and Husson, 2008) in R to identify whether there were differences in community composition between different management zones. To do this, nine different sites were identified based on the point where each of the three transects intersected each of the three management zones (see Figure 2.1). The rationale behind splitting up the zones further for this analysis was in response to preliminary analysis of our field observations, which suggested that there were distinct bird communities at finer scales than the three management zones that we originally identified. Then, a Bray-Curtis dissimilarity matrix and dendrogram were created to identify clusters of sites in the CM that were most similar in their bird species' communities (based on both species' identities and abundance). These clusters were then overlaid on the results of the ordination to help identify parts of the CM with similar bird communities. We chose to use both a dendrogram and NMDS ordination to identify clusters to ensure that our results were robust. All data manipulation and statistical analysis were undertaken in R version 3.1.3 (R Core Team, 2016).

2.3 Results

2.3.1 *Which Bird Species Occur and Breed in the CM and Which Species Are of Conservation Concern?*

Site Importance

A total of 125 bird species were recorded in the CM across all the surveys: 29 were resident species (recorded across all seasons of the survey); 87 were winter visitors and passage migrants; 9 species were noted as summering (Table 2.1). A total of 31 species were recorded for the first time in the CM. Notable records included (i) White Tailed Eagle (*Haliaeetus albicilla*), which was recorded in the December survey in transect two, zone two; this species has not been recorded in the CM for more than 40 years; (ii) Fourteen species which were confirmed breeding in the CM according to the BTO breeding evidence criteria (Little Grebe

Tachybaptus ruficollis, Little Bittern *Ixobrychus minutus*, Squacco Heron *Ardeola ralloides*, Red-Wattled Lapwing *Vanellus indicus*, White-Tailed Lapwing *Vanellus leucurus*, Whiskered Tern *Chlidonias hybrida*, Eurasian Collared Dove *Streptopelia decaocto*, Pied Kingfisher *Ceryle rudis*, Basra Reed Warbler *Acrocephalus griseldis*, Great Reed Warbler *Acrocephalus arundinaceus*, Graceful Prinia *Prinia gracilis*, Iraq Babbler *Turdoides altirostris*, Purple Swamphen *Porphyrio porphyrio*, and House Sparrow *Passer domesticus*; see Appendix 2 for detailed information about breeding status and more details).

Table 2. 1.Species Observations & Counts (Oct, 2013 – Jun, 2014) in the Iraqi Central Marsh. Scientific names are provided in Appendix 2.

Species (English Name)	**Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Black Francolin	0	2	4	6	1	0	4	2	2
Greylag Goose	7	0	77	10	0	0	0	0	0
Mallard	0	0	47	55	0	2	0	0	0
Northern Shoveler	0	0	46	0	0	0	0	0	0
Northern Pintail	0	0	400	175	15	0	0	0	0
Garganey	0	0	0	0	0	0	8	0	0
Eurasian Teal	0	0	66	168	45	47	0	0	0
Marbled Duck	0	0	35	5	10	0	22	0	0
Ferruginous Duck	0	8	21	0	10	0	0	0	0
Little Grebe	58	42	70	95	81	40	14	30	72
Great Crested Grebe	0	0	0	5	0	0	0	0	0
White Stork	0	0	380	200	40	0	0	0	0
African Sacred Ibis	0	0	0	2	0	0	0	0	0

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Glossy Ibis	0	0	25	9	2	230	10	0	11
Eurasian Bittern	0	1	0	2	2	2	2	0	1
Little Bittern	0	1	0	0	0	0	111	203	143
Black-crowned Night Heron	0	0	2	1	0	1	11	21	56
Squacco Heron	41	132	181	85	116	970	100	39	90
Cattle Egret	55	83	0	18	6	0	0	0	0
Grey Heron	3	13	1	0	51	23	11	0	0
Purple Heron	8	9	19	11	6	10	33	12	8
Great White Egret	0	0	0	0	10	12	0	0	0
Little Egret	74	68	1046	750	665	380	33	12	505
Great White pelican	0	0	533	500	150	0	0	0	0
Pygmy Cormorant	0	0	0	0	0	0	7	21	23
Great Cormorant	2	1	0	5	0	0	0	0	0
Black - winged Kite	0	0	0	1	0	0	0	0	0
White – tailed Sea Eagle	0	0	1	0	0	0	0	0	0
Cinereous Vulture	0	0	2	0	0	0	0	0	0
Short-toed Snake-eagle	0	0	0	0	2	0	0	0	0
Western Marsh Harrier	12	13	28	23	18	15	1	1	0
Pallid Harrier	0	1	0	1	0	1	0	0	0
Montagu's Harrier	0	0	0	0	1	0	0	0	0

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Eurasian Sparrow hawk	0	1	0	0	2	1	0	0	0
Long-legged Buzzard	0	0	0	1	0	0	0	0	0
Greater Spotted Eagle	0	0	0	1	0	2	1	0	0
Steppe Eagle	1	1	0	0	0	2	0	0	0
Common Kestrel	0	0	1	0	0	0	0	0	0
Eurasian Hobby	0	1	0	0	0	0	0	0	0
Water Rail	1	0	0	0	0	0	0	0	0
Little Crake	0	1	0	0	0	0	1	0	0
Spotted Crake	0	1	0	0	0	0	0	0	0
Purple Swamphen	0	8	0	3	0	7	18	0	2
Common Moorhen	15	17	10	22	13	2	3	2	11
Common Coot	0	4	87	245	125	14	0	0	0
Black-winged Stilt	28	14	25	236	44	17	136	42	75
Spur-winged Lapwing	1	0	0	0	0	2	19	9	7
Red-Wattled Lapwing	12	9	5	9	1	3	4	7	6
White-tailed Lapwing	21	12	24	154	90	40	57	45	48
Common Ringed Plover	9	6	4	10	3	0	0	0	0
Little Ringed Plover	0	2	0	0	0	0	3	2	0

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Kentish Plover	4	10	43	23	13	0	0	0	2
Common Snipe	1	0	0	1	0	2	21	0	0
Common Redshank	0	0	0	0	1	11	8	0	0
Marsh Sandpiper	0	6	0	19	8	28	0	0	0
Common Greenshank	1	0	0	0	0	0	2	0	0
Green Sandpiper	3	1	0	1	4	2	0	0	0
Wood Sandpiper	0	0	0	0	1	0	0	0	0
Terek Sandpiper	3	0	0	0	1	0	0	0	0
Common Sandpiper	3	6	8	4	5	4	8	7	0
Sanderling	0	0	0	1	0	0	0	0	0
Little Stint	0	1	0	5	1	0	6	3	0
Curlew Sandpiper	0	0	0	0	0	0	5	2	0
Ruff	0	0	0	0	0	1	85	6	0
Collared Pratincole	0	0	0	0	0	0	15	9	4
Slender-billed Gull	17	165	480	487	891	163	164	78	90
Black-headed Gull	0	35	130	246	685	232	149	17	0
Armenian Gull	0	2	2	5	6	21	5	0	0
Gull – billed Tern	2	10	0	0	0	0	0	9	0
Little Tern	11	3	0	0	0	0	20	9	16
Common tern	0	6	0	0	0	53	43	9	18
Whiskered Tern	53	81	639	741	279	113	61	125	63

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
White – winged Tern	0	0	0	0	0	0	0	21	0
Pin-tailed Sandgrouse	0	0	0	0	0	23	16	0	0
European Turtle-dove	0	0	0	0	0	0	0	5	0
Eurasian Collared Dove	16	21	36	26	35	23	17	14	6
Laughing Dove	0	1	2	13	3	5	7	2	0
Common Barn-owl	0	0	0	1	0	0	0	0	0
Egyptian Nightjar	0	0	0	0	0	0	0	1	0
White-breasted Kingfisher	9	17	25	38	30	25	10	4	7
Common Kingfisher	10	12	29	18	25	17	5	1	3
Pied Kingfisher	236	318	542	500	461	293	269	245	147
Blue-cheeked Bee-eater	10	9	0	0	0	0	28	0	0
European Bee-eater	0	0	0	0	0	0	8	0	0
Eurasian Hoopoe	0	0	0	0	0	1	0	0	0
Red-backed Shrike	3	0	0	0	0	0	0	52	0
Isabelline Shrike	6	8	12	25	5	2	0	0	0
Turkestan Isabelline Shrike	2	0	0	1	2	0	1	0	0
Lesser Grey Shrike	0	0	0	0	0	0	0	31	0
Eurasian Golden Oriole	0	0	0	0	0	0	0	1	0

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Hooded Crow	0	0	2	0	5	2	0	0	0
Mesopotamian Crow	0	0	2	0	0	1	0	0	0
Crested Lark	32	3	10	4	6	4	9	19	24
White - eared Bulbul	0	1	1	2	4	0	0	0	0
Sand Martin	0	2	0	0	0	27	54	5	2
Barn Swallow	5	0	0	0	11	29	38	35	12
Willow Warbler	0	0	0	0	0	0	1	0	0
Common Chiffchaff	7	20	38	48	34	8	18	0	0
Basra Reed Warbler	0	0	0	0	0	0	14	42	66
Great Reed Warbler	1	2	0	0	0	0	38	57	42
Sedge Warbler	0	2	0	0	0	0	1	2	0
Eurasian Reed-Warbler	0	0	0	0	1	0	0	2	0
Graceful Prinia	13	9	11	23	73	41	78	104	61
Iraq Babbler	5	7	11	25	27	9	58	17	11
Afghan (Common) Babbler	0	0	0	16	6	18	0	4	0
Common starling	0	42	105	252	549	47	2	1	0
Song Thrush	0	0	0	1	0	0	0	0	0
European Robin	0	2	5	1	0	0	0	0	0
Bluethroat	0	1	1	1	1	0	0	0	0
Rufous-tailed Scrub-robin	0	1	0	0	0	0	0	0	0

Species (English Name)	Counts for survey months (Oct, 2013 – Jun, 2014). Note October 2013 = 1 and June 2014 = 9.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Common Redstart	0	0	0	0	0	0	1	0	0
Whinchat	0	5	0	0	0	0	0	4	0
Common Stonechat	0	0	3	3	0	0	0	0	0
Northern Wheatear	0	0	0	0	0	6	8	0	0
Black-eared Wheatear	0	0	0	0	0	0	1	0	0
House Sparrow	221	142	158	102	158	75	140	70	58
Spanish Sparrow	0	0	0	0	0	6	8	0	0
Dead Sea Sparrow	50	450	54	0	30	10	15	4	0
Yellow Wagtail	0	2	0	0	0	43	86	1	0
Citrine Wagtail	1	0	0	1	1	4	4	0	0
White Wagtail	51	25	134	80	61	74	9	0	0
Water Pipit	5	26	22	20	16	2	1	0	0
Corn Bunting	0	0	0	1	0	0	0	0	0
Ortolan Bunting	0	0	0	0	0	0	1	0	0
Reed Bunting	0	0	0	0	1	0	0	0	0

Important bird species for conservation

The survey found 11 species that are important conservation priorities in the CM and are red listed by the IUCN (Table 2.2), and two endemic species (Basra Reed Warbler and Iraq Babbler), and three near endemic species (Black Francolin, Little Grebe, and Mesopotamian Crow) according to Salim and Porter (2015). In addition, there are two species that are regionally threatened (Pygmy Cormorant and Sacred Ibis) and four species that are regionally near threatened (Grey

Heron, Purple Heron, Western Marsh Harrier, and Common Kingfisher) in the Arabian Peninsula (Symes *et al.*, 2015).

Table 2. 2. Threatened bird species recorded in the CM by this study (details of numbers recorded are presented in the Table 2.1).

English name	Latin name	Conservation Status
Marbled Duck	*Marmaronetta angustirostris*	Vulnerable (IUCN)
Basra Reed Warbler	*Acrocephalus griseldis*	Endangered (IUCN)
Greater Spotted Eagle	*Aquila clanga*	Vulnerable (IUCN)
Eastern Imperial Eagle	*Aquila heliacal*	Vulnerable (IUCN)
Ferruginous Duck	*Aythya nyroca*	Near Threatened (IUCN)
Cinereous Vulture	*Aegypius monachus*	Near Threatened (IUCN)
Pallid Harrier	*Circus cyaneus*	Near Threatened (IUCN)
Little Grebe (subspecies)	*Tachybaptus ruficollis iraquensis.*	Near Threatened (IUCN)
Iraq Babbler	*Turdoides altirostris*	Least Concern (Restricted-range) (IUCN)
White-tailed Lapwing	*Vanellus leucurus*	Least Concern (Biome-restricted) (IUCN)

Dead Sea Sparrow	*Passer moabiticus*	Least Concern (Biome-restricted) (IUCN)

2.3.2 *Spatial Distribution of Bird Abundance and Diversity across the CM*

According to the data from the study survey, the greatest bird species abundance was in winter (December, January and February). The areas of the CM with the greatest abundance of birds was along transect two and in zone two. The highest species richness was in January and April along transect one, and in zone two. (Figures 2.2, 2.3, 2.4 and 2.5; see Tables 2.1 and the Appendix 2 for further details). We produced a candidate set of eight models based on our full, global model for each response variable (Table 2.3). Across all eight species abundance models, zone had a Relative Importance (RI) of 0.92, Julian day had an RI of 0.71 and transect had an RI of 0.09. The model averaged parameter estimates (Table 2.4) highlighted how zone two had the highest overall species abundance (β=5.74, SE = 1.87); however, species abundance did not appear to significantly decline from January to December (β=-0.01, SE = 0.01). Across all eight species richness models, zone had a Relative Importance (RI) of 1.00, Julian day had an RI of 0.74 and transect had an RI of 0.18. The model averaged parameter estimates (Table 2.4) highlighted how zone two had the highest overall species richness (β=9.37, SE = 1.62); however, species abundance did not appear to significantly decline from January to December (β=-0.01, SE = 0.01).

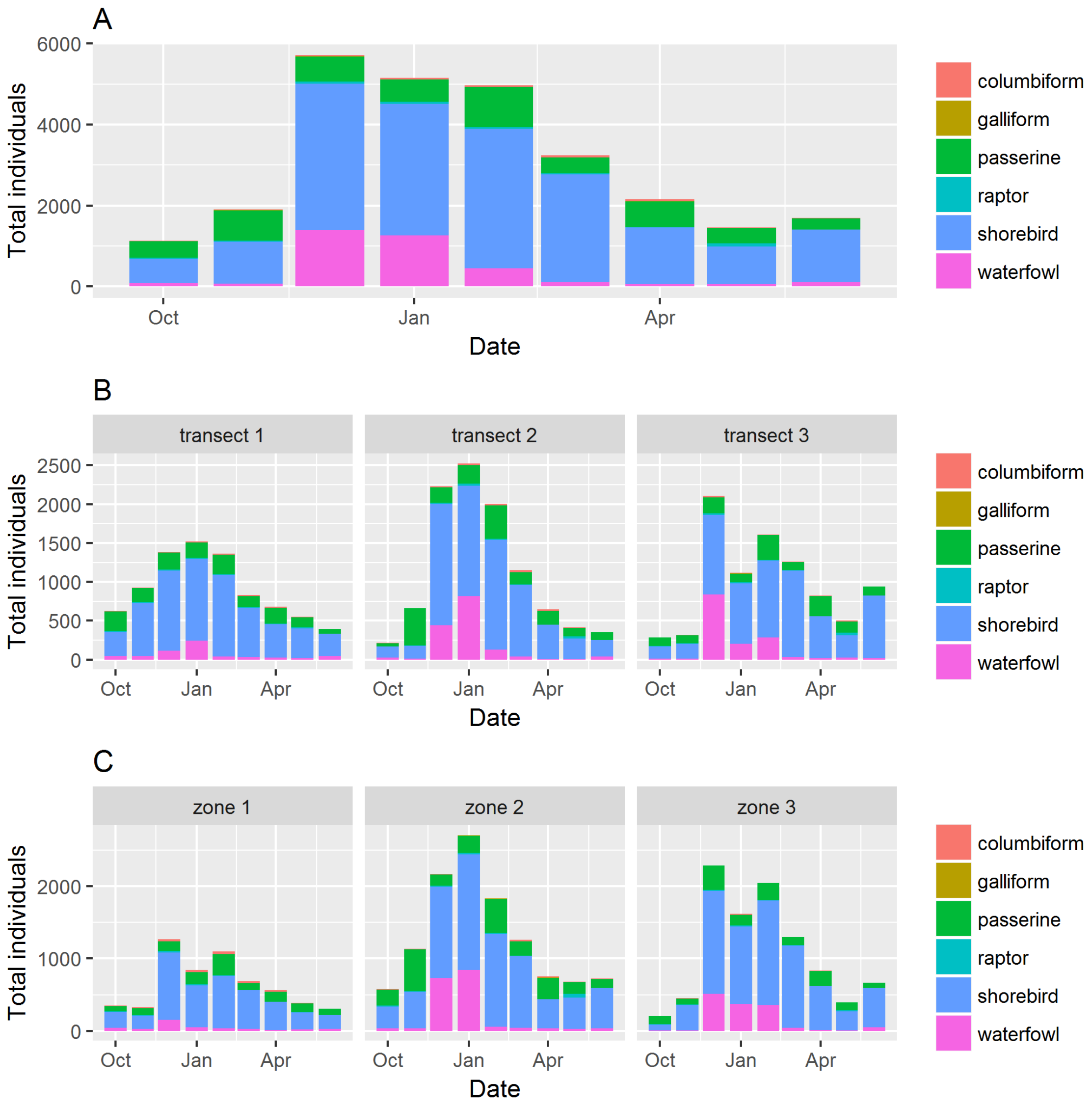


Figure 2. 2.Bird species abundance (all species observations summed) in the Iraqi CM (Monthly surveys from October 2013 – June 2014). A shows abundance for the whole CM, B shows abundance by transect and C shows abundance by zone. Bars are stacked by bird type.

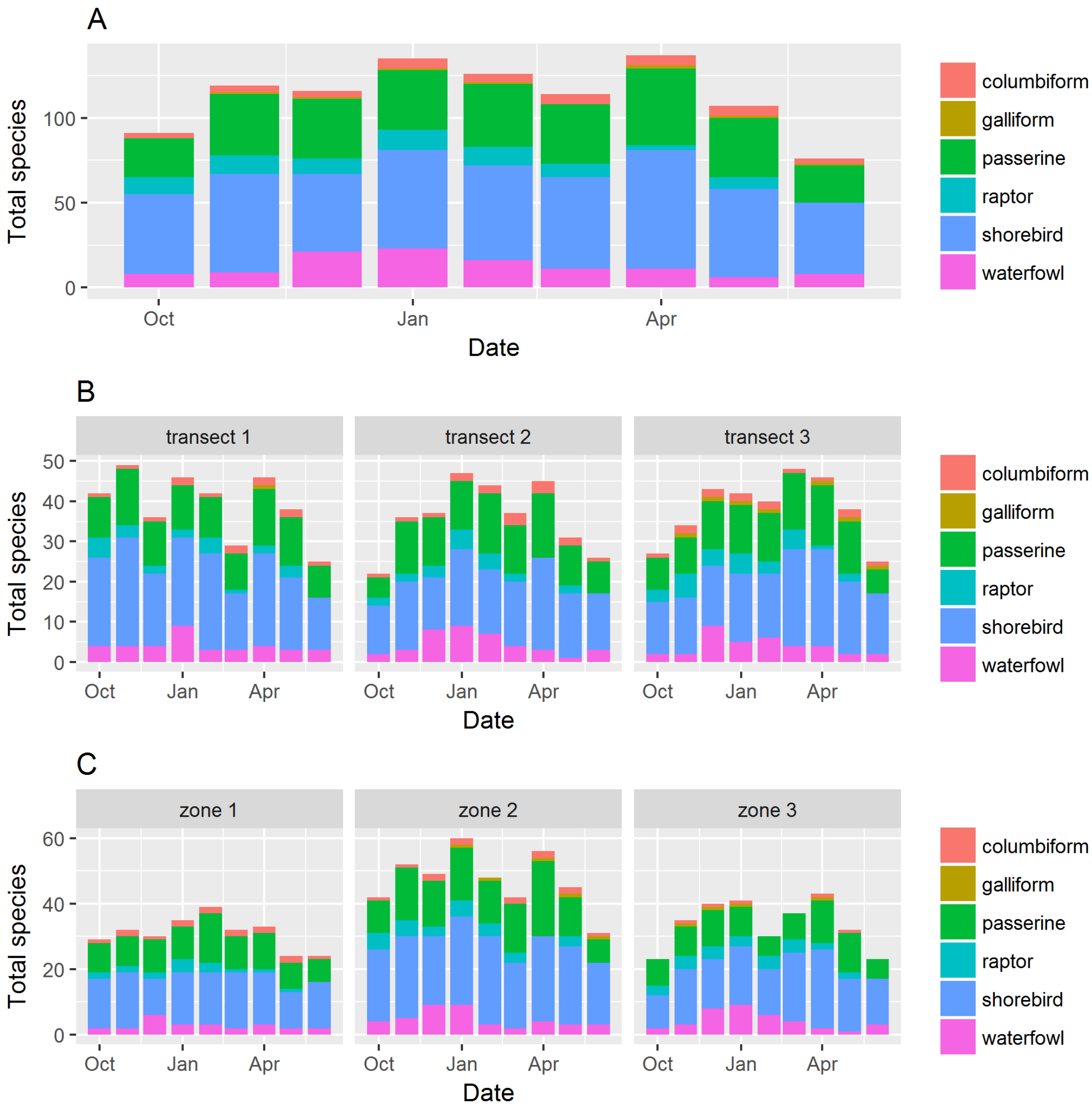


Figure 2. 3.Bird species richness in the Iraqi CM (monthly surveys from October 2013 – June 2014). A shows species richness for the whole CM, B shows species richness by transect and C shows species richness by zone. Bars are stacked by bird type.

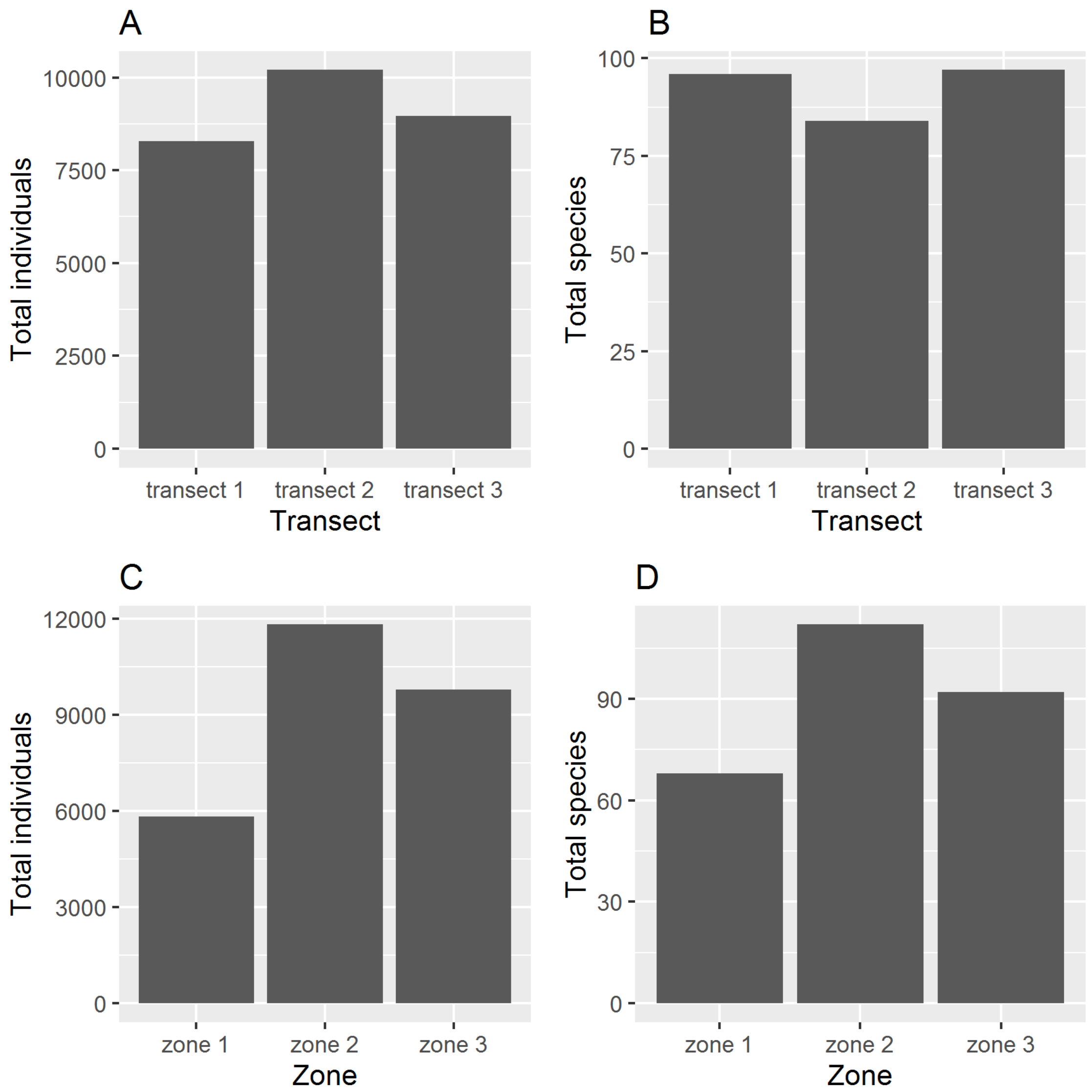


Figure 2. 4. Bird species richness in the Iraqi CM (monthly surveys from October 2013 – June 2014). A and B show species abundance for the three transects and the three zones in the CM, and C and D show species richness by the three transects and the three zones.

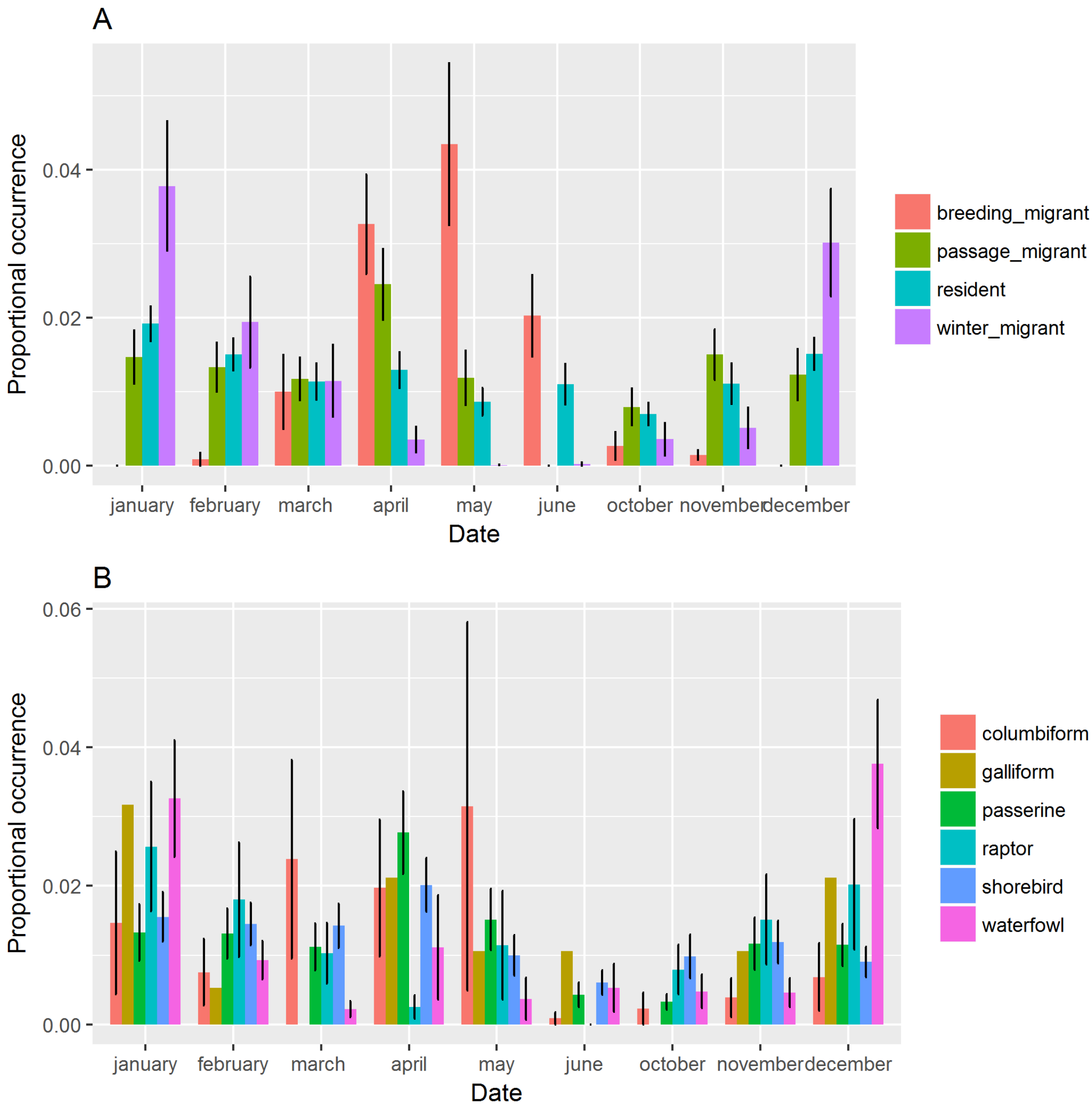


Figure 2. 5. Mean ± 1SE proportional occurrence of different bird groups in the Iraqi CM split by date (monthly surveys from October 2013 – June 2014). A shows species grouped by migratory status and B shows species grouped by broad taxonomic group. Proportional occurrence was calculated so the monthly count for each species was divided by the total count for that species across the entirety of the study period, which was then averaged across each bird group.

2.3.3 *What Bird Assemblages Exist within Different Zones in the CM?*

The dendrogram based on the Bray-Curtis dissimilarity matrix showed that there were at least two main clusters of bird species, with potentially a third cluster. These results were aligned with the site cluster analysis undertaken using NMDS ordination, which shows that the study area can be categorised into three main clusters of bird species (cluster one = T1-Z1, T1-Z2, T2-Z1, and T3-Z1; cluster 2 = T1-Z3, T2-Z2, T2-Z3, T3-Z2, and T3-Z3; Figures 2.6 and 2.7). Some of the bird species found in cluster one include Eurasian Bittern (*Botaurus stellaris*), Cattle Egret (*Bubulcus ibis*), Moorhen (*Gallinula chloropus*), Little Tern (*Sternula albifrons*), Water Pipit (*Anthus spinoletta*), House Sparrow (*Passer domesticus*), Cormorant (*Phalacrocorax carbo*), and Sedge Warbler (*Acrocephalus schoenobaenus*). We found Common Babbler (*Turdoides caudata*), Lesser Grey Shrike (*Lanius minor*), Mallard (*Anas platyrhynchos)*, Armenian Gull (*Larus armenicus*), Crested Lark (*Galerida cristata*), Dead Sea Sparrow (*Passer moabiticus*), and Collared Pratincole (*Glareola pratincola*) among others within cluster two. Finally, cluster three contained Pallid Harrier (*Circus macrourus*), Greylag Goose (*Anser anser*), Grey Heron (*Ardea cinerea*), and Great White Pelican (*Pelecanus onocrotalus*).

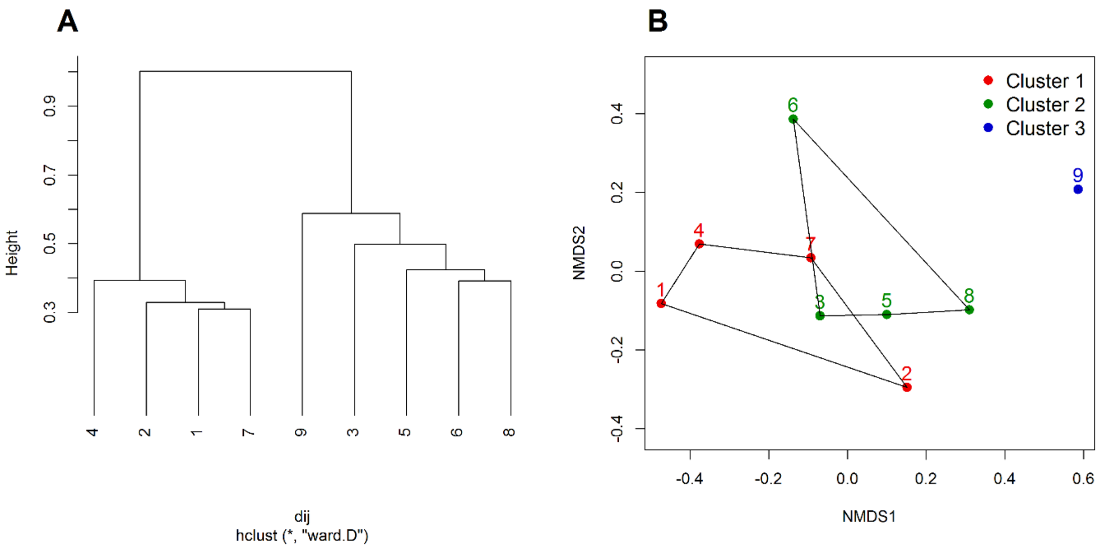


Figure 2. 6. NMDS cluster analysis for birds in the CM. A shows a dendrogram based on a Bray Curtis dissimilarity matrix. This dendrogram was then cut to give three groupings based on similarities in bird community composition as shown both by the dendrogram and by the NMDS ordination plot. B shows the results of the NMDS ordination, with each zone/transect complement (e.g. zone one - transect one is site one, zone one - transect two is site two etc.) coloured according to grouping and surrounded by a convex hull. The ordination shows three different groupings of sites (note: the inclusion of site three within cluster one does not represent a failing with our method but a consequence of the way NMDS plots are visualized).

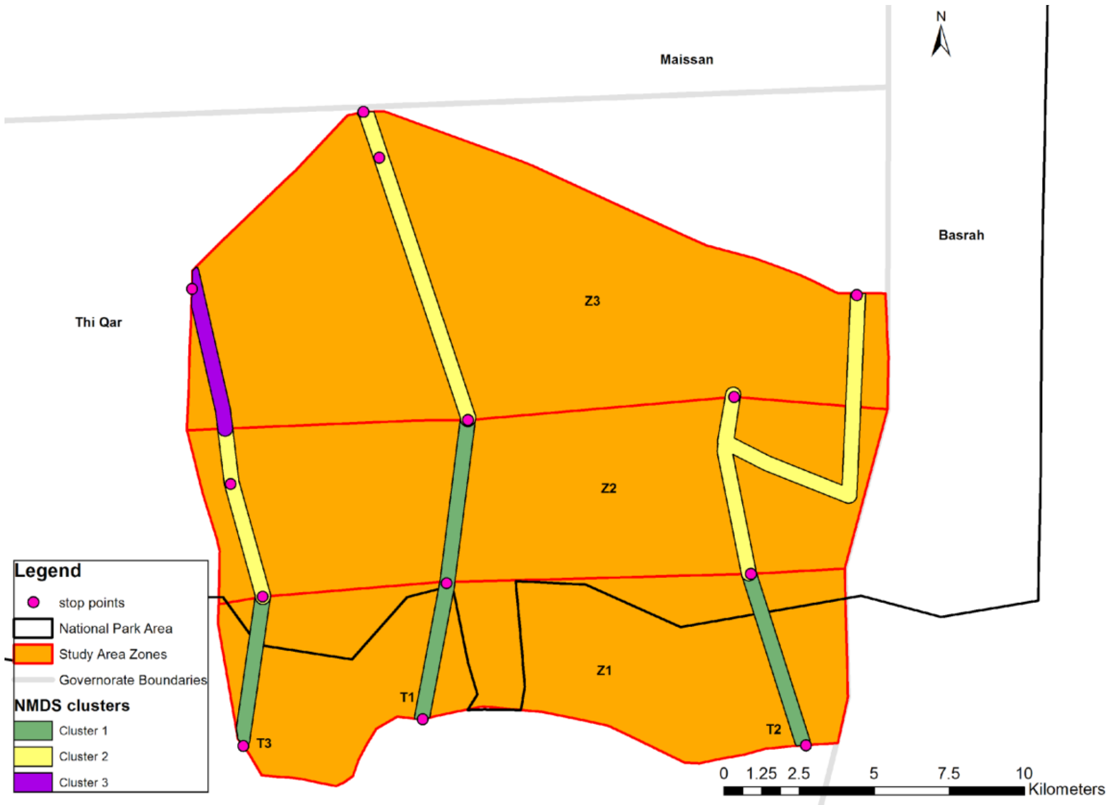


Figure 2. 7.NMDS cluster analysis for birds in the CM, surveys from October 2013 to June 2014 showing the spatial locations of the three different bird communities identified by the NMDS analysis.

Table 2. 3.Candidate models for model averaging for species abundance and richness. AICc refers to Akaike's Information Criterion corrected for small sample sizes; Δ refers to the difference in AICc between each model and the model with the lowest AICc in the subset; wt refers to the AICc weight.

Response variable	**Candidate model number**	**Fixed effects**	**Log Lik**	**AICc**	**Δ**	**wt**
Abundance	1	Intercept + julian + zone	-268.66	548.13	0.00	0.59
	2	Intercept + zone	-270.69	549.91	1.79	0.24
	3	Intercept + julian + transect + zone	-268.66	552.85	4.72	0.06
	4	Intercept + julian	-273.39	553.09	4.97	0.05

Response variable	Candidate model number	Fixed effects	Log Lik	AICc	Δ	wt
	5	Intercept + transect + zone	-270.69	554.51	6.38	0.02
	6	Intercept	-275.2	554.56	6.43	0.02
	7	Intercept + julian + transect	-273.39	557.57	9.44	0.01
	8	Intercept + transect	-275.2	558.92	10.79	0.00
Richness	1	Intercept + julian + zone	-250.71	512.24	0	0.61
	2	Intercept + zone	-252.9	514.35	2.11	0.21
	3	Intercept + julian + transect + zone	-249.82	515.23	2.98	0.14
	4	Intercept + transect + zone	-252.14	517.45	5.21	0.04
	5	Intercept + julian	-271.1	548.52	36.28	0
	6	Intercept	-272.21	548.57	36.33	0
	7	Intercept + julian + transect	-270.67	552.17	39.93	0
	8	Intercept + transect	-271.82	552.18	39.94	0

Table 2. 4.Model averaged parameter estimates for predictors of species abundance and richness in the CM.

Response variable	Fixed effects	Estimate	SE	CI 2.5%	CI 97.5%	Relative Importance
Abundance	(Intercept)	15.6	1.98	11.68	19.52	-
	Julian day	-0.01	0.01	-0.03	0.00	0.71
	zone2	5.74	1.87	2.01	9.48	0.92
	zone3	3.13	1.87	-0.61	6.86	0.92

	transect2	-0.01	1.91	-3.81	3.78	0.09
	transect3	0.18	1.91	-3.62	3.97	0.09
Richness	(Intercept)	21.72	1.71	18.33	25.11	-
	Julian day	-0.01	0.01	-0.02	0.00	0.74
	zone2	9.37	1.62	6.13	12.61	1.00
	zone3	-1.22	1.66	-4.52	2.09	1.00
	transect2	-1.93	1.66	-5.25	1.38	0.18
	transect3	-1.63	1.63	-4.87	1.61	0.18

2.4 Discussion

The Iraqi Central Marsh (CM) experienced major drainage in the early 1990s. Prior to this period eighty bird species were found in the last complete census in the 1970s (Evans, 2002). Here we report an increase in the diversity of bird species reported in the CM and note that all species recorded in the early 1990s were recorded in our survey. However, there are two important caveats here. First, the methods used by Evans (2002) differ from our methods as we used transect methodology across different months and spent more time during the days on surveys, and they used point counts for single seasons only. Second, the abundance of birds was not recorded by Evans (2002) so even though the diversity of bird species is higher now it is unclear what has happened to the abundance of bird species using the site.

We recorded 125 bird species in the CM over nine months of survey work, which increased the species list for the area by 24% and we confirmed the breeding of 14 species and coded 20 species as species observed in breeding season in suitable nesting habitat (H according to British Trust for Ornithology breeding status codes). Earlier work over a five-year period recorded 94 species using less intensive survey efforts (Nature Iraq, 2017). Fifty-one breeding bird species were reported by Salim et al. (2012) and 77 species were recorded by Salim and Porter

(2015) in the Iraqi southern marshland complex where the CM is found. In comparison to the wider region at large, 357 bird species were recorded in wetland conservation areas found in the Arabian Peninsula, Iraq, Syria, and Lebanon, covering an area of 3,000,000 km^2 (Symes *et al.*, 2015).

Our survey recorded 31 more bird species versus the most recent, rapid assessment which is potentially due to the nature of the previous surveys, which were rapid assessments of bird species undertaken across the entirety of the Mesopotamian marshlands (Hawiza Marsh to the east of the Tigress River, Hammar Marsh to the south of the Euphrates River, and the Central Marsh between the Tigress and Euphrates Rivers; Nature Iraq, 2017). By focusing on one of the marshes, we were able to conduct more intensive surveys, which detected more bird species. For this reason, there is a clear need to undertake further, intensive surveys in the other two Mesopotamian marshes to provide accurate, up-to-date information. It is impossible to compare our maximum counts in months to other wetlands in Iraq for key species because no other study has used the same intensive survey methods we have. With enhancements to our methodology we would like to repeat our method in other marshes where we hope to answer this question. Recent national water and biodiversity strategies have indicated that it is no longer appropriate to consider all three marshes as one conservation unit, as the connections between the water bodies have severely declined due to extreme water scarcity (Salim, Porter and Rubec, 2009). As such, there is an urgent need to develop management plans for each of the three Mesopotamian marshes.

The greatest bird species abundance in the CM was in winter (December, January, and February). The area of the CM with the greatest abundance of birds was along transect two and in zone two. The highest species richness was in January and April along transect one and in zone two. However, there is potential of seasonal and observer bias. In winter, larger birds often form flocks in open areas and are therefore easy to detect. In summer many breeding birds may be less easy to detect (i.e., hidden from view in the reeds). Similarly, in spring and autumn there will be huge numbers of migrant passerines using the marshes as a “stop-over” site to rest and feed. Our analysis is useful for comparing abundance and richness between areas within the same season but is perhaps less useful for comparing between seasons.

There has been recent interest in the potential population size of one of the most threatened species we recorded, the globally endangered Basra Reed Warbler (Al-Sheikhly, Nader and Barbanera, 2013, 2015; Porter *et al.*, 2015) . We recorded 11 nests in our study area (10 of them were independent nests; one in April, four in May, and five in June 2014). All recorded nests of Basra Reed Warbler in our surveys were built on reed stems only. Basra Reed Warbler shares its preferred reed bed habitat with the similar Great Reed Warbler. Our survey highlighted the dominance of Great Reed Warbler in April (the number of individuals recorded of Basra Reed Warbler in the area of study was 14, 42, and 66 and for Great Reed Warbler 38, 57, and 42 in April, May, and June 2014, resp.). It is unsafe to extrapolate from the numbers of nesting Basra Reed Warblers that we detected in our survey to the whole site, but clearly the Iraqi marshlands holds a substantial population of this globally endangered species.

Although the CM is the first national park to be designated in Iraq (Pearce, 2013) there is still a lack of detailed information on bird distribution across the site or in current management plans (Nature Iraq, 2017). The CM area was considered as a Key Biodiversity Area (KBA) and an Important Birds Areas site and was divided into two main areas: core and buffer zones (Alwash *et al.*, 2009; Ministry of Environment, 2014; Nature Iraq, 2017). Our study provides more detailed information about bird abundance, richness, and assemblages. Three bird clusters were suggested for the first time in the area with zone two identified as containing large numbers of breeding birds. In contrast zone one had fewer species and a lower overall abundance; due to the proximity of human settlements zone one is also likely to receive more human disturbance (fishing, reed cutting, and buffalo grazing) than the other zones. More analysis is needed for the data to highlight differences between the 3 clusters.

While our results add to the knowledge of bird species present in the CM, there are weaknesses in our study deriving from the survey methods. Relying on visual observation alone will mean our abundance estimates will be affected by the detectability of the different species. Thus, we may have underestimated the abundance of cryptic species in particular. Another weakness is that the point counts of birds coincide with the defined margins of the three 'ecotype' zones, yet these points were used to classify bird communities. This strategy reflected the logistical difficulties of sampling the CM. However, a point sampling strategy that samples within the zones more fully is recommended in future.

Water levels in the Euphrates River, the main source of the CM's water, varied between autumn, winter, and summer (1.29 m, 1.79 m, and 1.66 m in October 2013 and January and June 2014, resp.; see Table 2.5), which is the main source of control of water levels and water quality inside the CM (Pearce, 2013). Rising water levels in the winter expand the flooded area away from Chibayish City and provide more suitable habitats for water birds in zone three. In addition, rising water levels in the Euphrates enable easier access for local people in zone one. Thus, keeping the minimum water level at 1.29 m in summer and winter could help and support wildlife in the CM, especially in zone two and zone three.

Table 2. 5.Maximum and Minimum monthly water levels in the Euphrates River (Chibayish City station) from October 2013 – June 2014 (Official data of the Iraqi Ministry of Water Resources- Chibayish branch). Note 1 = October 2014 and 9 = June 2014.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Min cm	129	147	158	154	176	165	167	165	165
Max cm	148	172	172	179	169	170	172	167	166
During the survey	147	157	160	170	170	165	168	167	166

Our results clearly show that the CM provides habitat for many bird species and that more intensive survey methods are needed for other two marshes found within the Mesopotamian marshland complex. Owing to national water scarcity, there is a real danger that the Mesopotamian marshlands will shrink in size, reducing the effective area of suitable habitat for many wetland species. We provide detailed information on the bird species found within the CM (full details of breeding status, field notes, survey dates and conservation status are available in Appendix 2 Tables 2.6, 2.7, 2.8 and 2.9 respectively), which could help form the basis of a management plan for their conservation.

2.5 *Recommendations*

We make the following recommendations for management and future work relating to bird conservation in the CM:

(1) Limit local human activities in zone one and support the designation of zone one as a buffer for zones 2 and 3.

(2) Future bird monitoring studies should build upon our methods with a more stratified sampling regime recommended in future, i.e. dividing survey sections into 1km sections (cf 30km transects). Surveying should also be based on both visual and aural detection, and should use Distance sampling techniques to account for detectability. This could provide accurate population estimates for the entire site. Additionally, if possible, the direction of survey (north-south versus south-north) should be randomized.

(3) Ensure that water levels in the Euphrates River are maintained because this is the main source for CM’s water during summer and winter and is needed for bird populations.

(4) Following the establishment of a soil embankment between Chibayish City in Nasiriyah Province and Modina City in Basra Province, we recommend detailed analysis of water quality and sediments to evaluate the concentration of pesticides and heavy metals and their effects on bird species and other fauna in the CM.

(5) Evaluate local threats (e.g., hunting) and global potential threats (e.g., climate change) on the CM as a site and bird species in the area.
(6) Extend our findings on key species, for example, Basra Reed Warbler, to provide more precise estimates of population sizes within the CM.

Appendix 2

Table 2. 6.Appendix. Bird breeding statuses in the CM for April - June 2014. Key: T= transect and Z = zone.

Month	Species	Description
April	Red Wattled Lapwing	One nest with two Chicks and one egg in T2, Z2 (GPS Coordinates: 0706280, 3436379)
	Purple Swamphen	One empty nest T2, Z2
	Graceful Prinia	We did not count the numbers of nests
	Warbler	One empty nest in T2, Z3
	House Sparrow	We did not count the numbers of nests
	Iraq Babbler	One nest in T1, Z2
May	Warbler spp.	- Two empty nests of Warbler spp. in T1, Z3 (coordinates: 0683694, 3441836) - Two nests (with two chicks and one egg in each nest) of Basra Reed Warbler in T2, Z3 (coordinates: 0706003, 3441503 and 0705922, 3441499)
	Collared Dove	- Nest (with two eggs) of Collared Dove in T2, Z1

Month	Species	Description
	Whiskered Tern	- Chicks and large numbers of Whiskered Terns (two colonies; each colony had over 50 nests) located T2, Z3. Each nest was floating on water and all contained three eggs). [Coordinates: 0705878, 344280 and 0706394, 3437954].
	Little Bittern	- Nest of Little Bittern with 4 eggs in transect two [coordinates: 0702287, 3430598].
	White Tailed Lapwing	- Two Nests of White Tailed Lapwing (one nest with four eggs and second with two eggs) [Coordinates: 0684287, 3434033].
	Graceful Prinia	- Nest of Graceful Prinia in T3
	House Sparrow	- One nest and chicks of House Sparrow in T3
June	Warbler	- Three nests of Basra Reed Warbler with two chicks and one egg in T1, Z2 [Coordinates: 0693162, 3436719 and 0684284, 3434030]. - Three nests of Basra Reed Warbler in T2, Z3 [Coordinates: 0705880, 3441550 and 0705874, 3441525]. - All recorded nests of Basra Reed Warbler in our survey were built on reed stems only. - Basra Reed Warbler shares its preferred reed bed habitat with the similar Great Reed Warbler. - Our survey highlighted dominancy of Great Reed Warbler in April (number of individuals recorded of Basra Reed Warbler in the area of study was: 14, 42, 66, and for Great Reed Warbler was 38, 57, 42 in April, May, June 2014 respectively)
	Little Bittern	- Nest with four eggs and chick of Little Bittern in T2, Z1 [Coordinates: 0693170, 3436726].
	White Tailed Lapwing	- Nest with four eggs of White Tailed Lapwing in T2, Z1.

Month	Species	Description
	Collared Dove	- Nest with two eggs of Collared Dove in T2, Z1.
	Whiskered Tern	- 20 chicks of Whiskered Tern in T2, Z3
	Pied Kingfisher	- One chick and 10 eggs of Pied kingfisher in T1, Z2.
	Little grebe	- Observation 20 juveniles of Little grebe subspecies *Tachybaptus ruficollis iraquensis* in T2, Z3.

Table 2. 7.Appendix. Field notes and breeding evidence of birds from October 2013 to June, 2014 in the Iraqi Central Marsh.

Survey	Important Notes
Oct, 2013	● Wide distribution of Pied king fisher, Cattle Egret (especially on the back of the water buffalos), Crested Lark, House Sparrow. ● Recording Greylag Goose as first arrival in this month to the CM ● Recording Red-backed Shrike (we just recorded this species in Oct and May). ● Recording water Rail just in this month
Nov, 2013	● Wide distribution of Pied king fisher, Cattle Egret (especially on the back of the water buffalos), Crested Lark, and House Sparrow. ● Recording Starling, Coot, Yellow Wagtail, Robin, Armenian Gull, Ferruginous Duck, and Bluethroat as first arrival in this month to the CM ● Large number of Dead Sea Sparrow, Winchat compared with the observations of same species in the 9 surveys. ● Recording Little and Spotted Crake
Dec, 2013	● Reduction of Cattle Egret observations ● Dominant of Little Egret ● Appearance/Presence of Eagles and Vultures in the area of study (e.g. White Tailed Eagle and Black Vulture)

Survey	Important Notes
	● First arrivals of huge number of water birds and ducks to the area of study (e.g. Teal, Northern Pintail, Mallard, and Shoveler). ● Increasing of Common King Fisher, White breasted Kingfisher, White Wagtail, Marsh Harrier, Kentish Plover, Starling, Slender Bill and Black headed Gulls, Coot, and Chiffchaff. ● First arrival of White Stork and Pelican White ● First observation of Spanish Sparrow, Marbled Teal, Common Kestrel, and Glossy Ibis of the 9 surveys. ● Increasing of birds Hunting
Jan, 2014	● Dominant of Whiskered Tern and Little Egret ● Wide distribution of Black Winged Stilt ● Increasing of White Tailed Lapwing, Coot, Chiffchaff, Isabelline Shrike, and Gulls ● First Observation of Great Crested Grebe, Sacred Ibis, and Song thrush. ● Over hunting
Feb, 2014	● Fishing is forbidden in this month. Therefore, locals using over hunting of birds in the CM ● First observation of Grey Heron ● Dominant of Slender billed and black headed Gulls ● Decreased in numbers of Mallard, and ducks ● First observation of Barn Swallow, Terek Sandpiper, Common Redshank, Reed Bunting, Wood Sandpiper, Montague's Harrier, European Reed Warbler, Great White Egret, Short-Toed Snake Eagle
Mar, 2014	● Dominant and wide distribution of Squacco Heron in all transects and zones ● Decrease in the numbers of Little Egret ● Decrease of hunting ● Decrease in numbers of Starling, Water Pipit, Coot, ducks, ● Disappearing of Kentish Plover, Common Ringed Plover, Cattle Egret, White Stork, Pelican White, White Cheeked bulbul, Bluethroat, ● Highest observations/ numbers of Marsh Sandpiper, Yellow Wagtail, Common Tern, Glossy Ibis, and Common Redshank ● First observation of Spur-Winged Lapwing, Sand Marten, Pin –tailed Sandgrouse, and Northern Wheatear, Hoopoe, and Ruff
Apr, 2014	● Start of nesting of Iraq Babbler and House Sparrow ● Arrival of Warblers (Great Reed Warbler highest in numbers than Basra Reed Warbler) ● Disappearing of Marsh Harrier ● Dominant of Little Bittern and Great Reed Warbler ● Marbled Duck can be seen easily than other months

<table>
<tr><th>Survey</th><th>Important Notes</th></tr>
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Decrease in numbers of Squacco Heron, Common Kingfisher, White Breasted Kingfisher, Starling, Glossy Ibis, and Little Egret
Increase numbers of Glassful Prinia, Purple Swamphen, Northern Wheatear, Ruff, Spur-Winged Lapwing, and Purple Heron than other months
Night Heron can be seen easily
Observation of Blue – Cheeked Beater just in this month
Disappearing of Great White Egret, Common Babbler, Coot, Teal, and Marsh Sandpiper
First observation of Pygmy Cormorant, Willow Warbler, Collared Pratincole, European Bee-eater, Garganey, Curlew Sandpiper
Recording Greater-Spotted Eagle
Breeding evidences:

Nest with Chicks of Red Wattled Lapwing (GPS Coordinates 0706280, 3436379)
Empty nest of Purple Swamphen
Nests of Graceful Prinia
Empty nest of Warbler in transect 2
Nest of House Sparrow
Nest of Iraq Babbler

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<tr><td>May,
2014</td><td>

Increase in numbers of Graceful Prinia, Basra Reed Warbler, and Pygmy Cormorant
Decrease in numbers of Gulls and Whiskered Tern
Arrival of Red – Backed Shrike
Recording Winchat, Golden Oriole, White-winged Black Tern, and European Reed Warbler
First observation of Lesser Grey Shrike, European Nightjar, and Turtle Dove
Disappearing of Grey Heron, Chiffchaff, Citrine Wagtail, Redshank, Northern Wheatear and White Wagtail
Breeding evidences:

Empty 2 nests of Warbles in transect 1, zone 3 (coordinates: 0683694, 3441836)
Two nests (with 2 chicks and one egg in each nest) of Basra Reed Warbler in Transect 2, zone 3 (coordinates: 0706003, 3441503 and 0705922, 3441499)
Nest (with 2 eggs) of Collared Dove in transect 2, zone 1
Chicks and huge numbers (2 colonies; each colony has more than 50 nest) of Whiskered Tern nests in transect 2, zone 3 (Each nest is floating on the water with 3 eggs) coordinates: 0705878, 344280 and 0706394, 3437954.
Nest of Little Bittern with 4 eggs in transect 2 (coordinates: 0702287, 3430598

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Survey	Important Notes
	➢ Two Nests of White Tailed Lapwing (one nest with 4 eggs and the second with 2 eggs) coordinates:0684287, 3434033 ➢ Nest of Graceful Prinia in transect 3 ➢ Nest and chicks of House Sparrow in transect 3.
Jun, 2014	● Increasing in numbers of Night Heron and Pygmy Cormorant (especially in transect 3), Little Grebe, Moorhen, and Crested Lark ● Assemblage of little Egret in one huge group in transect 3 ● Disappearing of Marsh Harrier, Starling, Black Headed Gull, Red- Backed Shrike, Yellow Wagtail, Armenian Gull, European Reed Warbler, Ruff, and Lesser Grey Shrike ● Breeding evidences: ➢ Three nests of Basra Reed Warbler with 2 chicks and one egg in transect 1, zone 2 (coordinates: 0693162, 3436719 and 0684284, 3434030 ➢ Three nests of Basra reed Warbler in transect 2, zone 3(Coordinates: 0705880, 3441550 and 0705874, 3441525) ➢ Nest with 4 eggs and chick of Little Bittern in transect 2, zone 1 (coordinates: 0693170, 3436726) ➢ Nest with 4 eggs of White Tailed Lapwing in transect 2, zone1 ➢ Nest with 2 eggs of Collared Dove in transect 2, zone 1 ➢ Chicks of Whiskered Tern in transect 2, zone 3 ➢ Chick and eggs of Pied kingfisher ➢ Observation Juveniles of Little grebe subspecies *Tachybaptus ruficollis iraquensis* in transect 2, zone 3

Table 2. 8.Appendix. List of survey dates in the Central Marsh.

Month	**Oct, 2013**	**Nov, 2013**	**Dec, 2013**	**Jan, 2014**	**Feb, 2014**	**Mar, 2014**	**Apr, 2014**	**May, 2014**	**Jun, 2014**
Day of the survey	28	9	16	17	17	19	16	17	9
	29	10	17	19	18	20	17	18	10
		11	18	20	19	21	18	19	11

Table 2. 9.Appendix. The status of birds in the Central Marshes, southern Iraq. Survey from Oct, 2013 – Jun, 2014 Key: IUCN Red List category (ver. 3.1.); Status in Iraq (Salim et al. 2012); Months recorded; highest count; Status in the CM based on the study survey; Breeding status in CM with BTO breeding code.

Family	**English Name**	**Scientific name**	**IUCN Red List category**	**Status in Iraq (Salim et al. 2012)**	**Status in the CM based on the survey by Nadheer Fazaa**	**Month of observation**	**Highest Count**	**Breeding status in CM with BTO breeding code**
Phasianidae	Black Francolin	*Francolinus francolinus*	Least Concern	Breeding resident, mainly in the north , northeast and along the Tigress and Euphrates Rivers	Resident	Nov, Dec, Jan, Feb, Apr, May, and Jun	Almost same number 2-6	H

Anatidae	Greylag Goose	*Anser anser*	Least concern	Local breeding resident in small numbers in the southern marshes; widespread winter visitor to wetlands and agricultural land	Winter visitor	Oct, Dec, and Jan	Dec. 77	not seen in the breeding season
	Mallard	*Anas platyrhynchos*	Least Concern	Fairly widespread passage migrant and winter visitor , some remain in summer	Winter visitor	Dec, Jan, and Mar	Jan. 55	Not seen in the breeding season
	Northern Shoveler	*Spatula clypeata*	Least Concern	Fairly widespread passage migrant and winter visitor, especially	Winter visitor	Dec	Dec. 46	Not seen in the breeding season

				frequent in southern marshes, some remain in Summer				
	Northern Pintail	*Anas acuta*	Least concern	Fairly widespread passage migrant and winter visitor, especially frequent in southern marshes	Winter visitor	Dec, Jan, Feb	Dec. 400	Not seen in the breeding season
	Garganey	*Spatula querquedula*	Least Concern	Fairly widespread passage migrant, rare in winter, may breed	Passage migrant	Apr	Apr.8	M, H
	Eurasian Teal	*Anas crecca*	Least Concern	Fairly widespread passage migrant and winter visitor, especially frequent in	Winter visitor	Dec, Jan, Feb, and Mar	Jan. 168	Not seen in the breeding season

				southern marshes				
	Marbled Duck	*Marmaronetta angustirostris*	Vulnerable	Local breeding resident in wetlands in central Iraq, more widespread in southern marshes, where wintering population is probably largest in the world	Winter visitor and possible breeds	Dec, Jan, Feb, and Apr*	Dec.35	H
	Ferruginous Duck	*Aythya nyroca*	Near Threatened	Local breeding resident in Southern and Central Iraq; uncommon passage	Winter visitor	Nov, Dec, and Feb	Dec. 21	Not seen in the breeding season

				migrant and winter visitor				
Podicipitidae	Little Grebe	*Tachybaptus ruficollis*	Least concern	Widespread breeding resident in the southern marshes and Central wetlands; widespread winter visitor. Resident birds are of the endemic race *iraquensis*	Resident	Oct to Jun Jan, Feb, and Jun	Jan.95	H, FL juveniles were seen, especially for endemic *iraquensis*
	Great Crested Grebe	*Podiceps cristatus*	Least Concern	Very local breeding resident in marshes and lakes of Southern Iraq; widespread winter visitor	Winter visitor	Jan	Jan.5	Not seen in the breeding season

Ciconiidae	White Stork	*Ciconia ciconia*	Least concern	Breeding summer visitor to northern and eastern Iraq; passage migrant, occasional in winter	Passage migrant and winter visitor	Dec, Jan, Feb	Dec.380	Non – breeding (not seen in the breeding season)
Threskiornithidae	African Sacred Ibis	*Threskiornis aethiopicus*	Least Concern	Very local breeding resident in dense reedbeds in the southern marshes. The southern marshes hold the only regular breeding colony in the Middle East, though there is feral colony in the	Winter visitor	Jan	Jan. 2	Not seen in the breeding season

				United Arab Emirates.				
	Glossy Ibis	*Plegadis falcinellus*	Least concern	Resident, breeding very locally in dense reed vegetation in the southern marshes; also a passage migrant and winter visitor	Winter visitor	Dec, Jan, Feb, Mar, and Apr	Mar.230	Non-breeding (not seen in the breeding season)
Ardeidae	Eurasian Bittern	*Botaurus stellaris*	Least concern	Passage migrant and winter visitor to the southern and central marshes, also occasionally in north Iraq; may breed in	Resident	Nov, Jan, Feb, Mar, Apr, and Jun	Same number of individual s in each month. 2	U, H

				southern marshes				
	Little Bittern	*Ixobrychus minutus*	Least concern	Breeding, summer visitor to many wetlands throughout Iraq, but rather local outside the southern marshes; also passage migrant, with a few wintering	Breeding and summer visitor	Apr, May, and Jun	May.203	NE, NY, FF, ON, FL, UN,
	Black-crowned Night Heron	*Nycticorax nycticorax*	Least concern	Breeding summer visitor or resident in southern and central wetlands;	Resident	Dec, Jan, Mar, Apr, May, Jun	Jun. 56	U, H

				local breeding summer visitor in north; passage migrant and winter visitor				
	Squacco Heron	*Ardeola ralloides*	Least concern	Breeding, summer visitor to southern marshes, more local in central and north Iraq; widespread passage migrant, occasional in winter	resident	Oct to Jun	Mar. 970	FL
	Cattle Egret	*Bubulcus ibis*	Least concern	Local breeding resident in central and southern wetlands,	Winter visitor	Oct, Nov, Jan, and Feb	Oct and Nov. 83	Non – breeding (Not seen in breeding season)

				widespread passage migrant, occasional in winter				
	Grey Heron	*Ardea cinerea*	Least concern	Fairly widespread passage migrant and winter visitor to southern marshes	Passage migrant and winter visitor	Oct to Apr	Feb.51	M
	Purple Heron	*Ardea purpurea*	Least concern	Breeding, summer visitor to southern marshes and probable breeder, very locally, in central and northern wetlands; passage migrant, a few in winter	Resident	Oct to Jun	Apr. 33	H,U

	Great White Egret	*Ardea* alba	Least concern	Passage migrant and winter visitor, most common in southern marshes, where some remain in summer	Passage migrant and winter visitor	Fab and Mar	Fab and Mar. 10-12	Non breeding (not seen in breeding season)
	Little Egret	*Egretta garzetta*	Least concern	Resident or breeding summer visitor to the dense reed beds of the southern marshes, also to one site in northern Iraq; widespread passage migrant and winter visitor	Resident	Oct to Jun	Dec and Jan. 1046	U, H

Pelecanidae	Great White pelican	*Pelecanus onocrotalus*	Least Concern	Fairly widespread passage migrant also winter visitor to southern and central wetlands	Passage migrant and winter visitor	Dec, Jan, Feb	Dec and Jan. 500 - 533	Not seen in the breeding season
Phalacrocorcidae	Pygmy Cormorant	*Microcarbo pygmaeus*	Least Concern	Breeding resident in dense reed vegetation in southern marshes; fairly widespread winter visitor.	Resident	Apr, May, and Jun	May and June. 21-23	U, H
	Great Cormorant	*Phalacrocorax carbo*	Least Concern	Fairly widespread passage migrant and winter visitor	Winter visitor	Oct, Nov, Jan	Jan. 5	Not seen in the breeding season
Accipitrida	Black - winged Kite	*Elanus caeruleus*	Least Concern	Uncommon and local breeding resident in central and	Passage	Jan	Jan. 1	Not seen in the breeding season

				south Iraq; number increasing and recently recorded in northern Iraq. Breeds near cultivated fields nesting especially in *Eucalyptus* and date palm				
	White –tailed Sea Eagle	*Haliaeetus albicilla*	Least Concern	Former winter visitor in small numbers, not recorded since 1940s	Passage migrant	Dec	Dec. 1	Not seen in the breeding season
Aegypiidea	Cinereous Vulture	*Aegypius monachus*	Near Threatened	Rare winter visitor to southern and central Iraq with one in summer in northeast	Passage migrant	Dec	Dec. 2	Not seen in the breeding season

Accipitrida	Short-toed Snake-eagle	*Circaetus gallicus*	Least Concern	Breeding summer visitor to the mountains of north Iraq; also a passage migrant	Passage migrant and winter visitor	Feb	Feb. 2	Not seen in the breeding season
	Western Marsh Harrier	*Circus aeruginosus*	Least Concern	Local breeding resident in southern marshes and possibly central wetlands; also a passage migrant and winter visitor	Resident	Oct to May Dec and Jan	Dec. 28	M
	Pallid Harrier	*Circus macrourus*	Near Threatened	Passage migrant and winter visitor, fairly widespread	Passage migrant and winter visitor	Nov, Jan, and Mar	Same number. 1	Not seen in the breeding season

	Montagu's Harrier	*Circus pygargus*	Least Concern	Fairly widespread passage migrant; some winter	Passage migrant	Feb	Feb. 1	Not seen in the breeding season
	Eurasian Sparrowhawk	*Accipiter nisus*	Least Concern	Widespread passage migrant and winter visitor	Passage migrant and winter visitor	Nov, Feb, and Mar	Feb. 2	Not seen in the breeding season
	Long-legged Buzzard	*Buteo rufinus*	Least Concern	Breeding resident in the mountains and hills of northern Iraq; widespread passage migrant and winter visitor	Passage migrant and winter visitor	Jan	Jan. 1	Not seen in the breeding season
	Greater Spotted Eagle	*Clanga clanga*	Vulnerable	Rather uncommon passage migrant and winter visitor, widespread but most	Passage migrant	Jan, Mar, and Apr	Mar. 2	M

				frequent in the southern marshes				
	Steppe Eagle	*Aquila nipalensis*	Least Concern	Fairly widespread passage migrant and winter visitor	Passage migrant and winter visitor	Oct, Nov, and Mar	Mar. 2	Not seen in the breeding season
Falconidae	Common Kestrel	*Falco tinnunculus*	Least Concern	Widespread breeding resident; also winter visitor	Passage migrant	Dec	Dec. 1	Not seen in the breeding season
	Eurasian Hobby	*Falco subbuteo*	Least Concern	Fairly widespread passage migrant; there is no evidence of breeding , though this is likely as birds have been observed during the	Passage migrant	Nov	Nov. 1	Not seen in the breeding season

				summer in northern Iraq, and the species breeds fairly commonly in southeast Turkey				
Rallidae	Water Rail	*Rallus aquaticus*	Least concern	Fairly wide spread passage migrant and winter visitor	Passage migrant and winter visitor	Oct	Oct. 1	Not seen in the breeding season
	Little Crake	*Zapornia parva*	Least concern	Passage migrant and winter visitor , one breeding record from central Iraq	Passage migrant and winter visitor	Nov and Apr One individual recorded in each month	Nov and Apr One individual recorded in each month	M
	Spotted Crake	*Porzana porzana*	Least concern	Passage migrant , but rarely observed	Passage migrant and winter visitor	Nov	Nov. 1	Not seen in the breeding season

	Purple Swamphen	*Porphyrio porphyrio*	Least Concern	Breeding resident in dense reed beds and dense aquatic vegetation along rivers in southern and central Iraq, very locally in wetlands in the north	Resident	Nov, Jan, Mar, Apr, and Jun	Apr. 18	H,UN
	Common Moorhen	Gallinula chloropus	Least Concern	Widespread breeding resident in wetlands in southern and central Iraq, locally in north; also a passage migrant and winter visitor	Resident	Oct to Jun Jan	Jan. 22	H

	Common Coot	*Fulica atra*	Least Concern	Breeding resident in very small numbers mainly in the south; widespread passage migrant and winter visitor , especially in the Southern marshes	Winter visitor	Nov to Mar Jan and Feb	Jan. 245	Not seen in the breeding season
Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	Least concern	Widespread breeding resident in southern, Central and Western wetlands, passage migrant and winter visitor	Resident	Oct to Jun, Jan	Jan. 236	U, H

Charadriidae	Spur-winged Lapwing	*Vanellus spinosus*	Least concern	Breeding resident in Central and Southern Iraq; passage migrant	Summer visitor and possible breeding	Oct, Mar, Apr, May, Jun	Apr. 19	H, S, T, U
	Red- wattled Lapwing	*Vanellus indicus*	Least concern	Widespread breeding resident in South, Central, Western andD Northeast Iraq in wetlands and farmlands; may breed in North where present in Summer	Resident	Oct to Jun Oct	Oct. 12	NY, NE, FF, ON, FL, UN
	White-tailed Lapwing	*Vanellus leucuraus*	Least concern	Local breeding resident in the wetlands	Resident	Oct to Jun Jan and Feb	Jan. 154	NY, NE, FF, ON, FL, UN,

				of southern, central and western Iraq; more widespread passage migrant , including to northern Iraq were also found in summer and maybe breed				
	Common Ringed Plover	*Charadrius hiaticula*	Least concern	Widespread passage migrant and winter visitor	Passage and winter visitor	Oct, Nov, Dec, Jan*, Feb	Jan. 10	Non-breeding
	Little Ringed Plover	*Charadrius dubius*	Least concern	Widespread breeding summer visitor mostly to northern and central Iraq, maybe breed in the south passage	Passage migrant	Nov, Apr, May, and Jun	almost same number in each month 2-3	U

				migrant with some remaining in winter				
	Kentish Plover	*Charadrius alexandrinus*	Least concern	Breeding resident in central and southern Iraq; passage migrant and winter visitor	Resident, but not seen in Mar, Apr, and May	Oct, Nov, Dec, Jan, Feb, and Jun	Dec. 43	H
Scolopacidae	Common Snipe	*Gallinago gallinago*	Least concern	Widespread passage migrant and winter visitor	Passage migrant and winter visitor	Oct, Jan, Mar, and Apr	Apr. 21	M
	Common Redshank	*Tringa totanus*	Least concern	Widespread passage migrant and winter visitor, some remain in summer	Passage migrant and winter visitor	Feb, Mar, and Apr	Mar. 11	M
	Marsh Sandpiper	*Tringa stagnatilis*	Least concern	Passage migrant and winter visitor mainly in	Passage migrant and winter visitor	Nov, Jan, Feb, and Mar	Mar. 28	M

				South and East				
	Common Greenshank	*Tringa nebularia*	Least Concern	Widespread passage migrant and winter visitor	Passage migrant and winter visitor	Oct and Apr	Almost same number. 1-2	M
	Green Sandpiper	*Tringa ochropus*	Least concern	Widespread passage migrant and winter visitor	Passage migrant and winter visitor	Oct, Nov, Jan, Feb, and Mar	Feb. 4	Non breeding (not seen in the breeding season)
	Wood Sandpiper	*Tringa glareola*	Least concern	Passage migrant and winter visitor in small numbers mainly to the South	Passage migrant and winter visitor	Feb	Feb. 1	Not seen in breeding season
	Terek Sandpiper	*Xenus cinereus*	Least Concern	Passage migrant and winter visitor mainly in	Passage migrant and winter visitor	Oct and Feb	Oct. 3	Not seen in the breeding season

				southern Iraq				
	Common Sandpiper	*Actitis hypoleucos*	Least concern	Fairly widespread passage migrant and winter visitor, a few remaining in summer, may breed in the mountains of Northern Iraq	Passage migrant and winter visitor	Oct to May	Almost same numbers 6-8	U
	Sanderling	*Calidris alba*	Least Concern	Passage migrant mainly in the southern tidal areas, some remaining in winter	Passage migrant and winter visitor	Jan	Jan. 1	Not seen in the breeding season

	Little Stint	*Calidris minuta*	Least concern	Passage migrant and winter visitor to Southern and Central Iraq	Passage migrant and winter visitor	Nov, Jan, Feb, Apr, and May	Jan and Apr. 5-6	M
	Curlew Sandpiper	*Calidris ferruginea*	Least concern	Passage migrant and winter visitor mainly to Central and Southern Iraq	Passage migrant	April and May	April. 5	M
	Ruff	*Calidris pugnax*	Least concern	Fairly widespread passage migrant and winter visitor	Passage migrant and winter visitor	Mar, Apr, and May	Apr. 85	M
Glareolidae	Collared Pratincole	*Glareola pratincola*	Least concern	Widespread breeding summer visitor to dry grassland areas near wetlands; passage migrant	Summerin g site, and possible breeding site	Apr, May, and Jun	Apr. 15	U, H, S

Laridae	Slender-billed Gull	*Larus genei*	Least concern	Breeding resident in Central and southern Iraq; breeding resident or summer visitor to the North; passage migrant and winter visitor	Resident	Oct to Jun	Feb. 891	M, H
	Black-headed Gull	*Larus ridibundus*	Least concern	Local breeding resident or summer visitor in northern Iraq; widespread winter visitor	Winter visitor	Nov to May	Feb. 685	M
	Armenian Gull	*Larus armenicus*	Least concern	Widespread winter visitor and passage migrant	Winter visitor	Nov to Apr	Mar. 21	M

	Gull – billed Tern	*Gelochelidon nilotica*	Least concern	Local breeding summer visitor in the extreme south; passage migrant, a few in winter	Passage migrant	Oct, Nov, and May	almost same number 9-10	U
	Little Tern	*Sternula albifrons*	Least concern	Fairly widespread breeding summer visitor and passage migrant	Summer visitor	Oct, Nov, Apr, May Jun	Apr. 20	U, H
	Common tern	*Sterna hirundo*	Least concern	Local breeding summer visitor to inland wetlands; passage migrant with a few remaining in winter	Summerin g site, and possible breeding site	Nov, Mar, Apr, May, Jun	Mar. 53	H, M

	Whiskered Tern	*Chlidonias hybrida*	Least concern	Resident and breeding summer visitor to wetlands in Southern Iraq; fairly widespread passage migrant; winter visitor, but not in the North	Resident and breeding	Oct to Jun	Jan. 741	NY, NE, FF, ON, FL, UN Colonise, and large number of nesting
	White – winged Tern	*Chlidonias leucopterus*	Least Concern	Local breeding summer visitor to wetlands in southern Iraq, fairly widespread passage migrant	Summer visitor	May	May. 21	U, H
Pteroclidae	Pin-tailed Sandgrouse	*Pterocles alchata*	Least Concern	Widespread but local breeding resident in	passage	Mar and Apr	same number 16-23	F

				dry grasslands				
Columbidae	European Turtle-dove	*Streptopelia turtur*	Least Concern	Local breeding summer visitor to woodlands, orchards and date palms; winter visitor	Summer visitor and possible breeds	May	May. 5	H
	Eurasian Collared Dove	*Streptopelia decaocto*	Least Concern	Widespread breeding resident	Resident and breeds	Oct to Jun *	almost same number 20 - 36	NY, NE, FF, ON, UN,
	Laughing Dove	*Spilopelia senegalensis*	Least Concern	Fairly widespread breeding resident. Until at least 1969s it was a rare winter visitor	Resident and possible breeds	Nov to may	Jan. 13	H

Tytonidae	Common Barn-owl	*Tyto alba*	Least Concern	Local, but fairly widespread breeding resident	passage	Jan	Jan. 1	Not seen in the breeding season
Caprimulgidae	Egyptian Nightjar	*Caprimulgus aegyptius*	Least Concern	Breeding summer visitor to semi-deserts and arid areas of southern and central Iraq, and possibly northeast; passage migrant in south and central Iraq	Passage migrant	May	May. 1	H (This bird is on its breeding territory)
Halcyonidae	White-breasted Kingfisher	*Halcyon smyrnensis*	Least concern	Breeding resident on rivers and in wetlands of southern, central and northeast Iraq, very	Resident	Oct to Jun	Jan and Feb. 30-38	H, S

				local elsewhere				
Alcedinidae	Common Kingfisher	*Alcedo atthis*	Least concern	Uncommon breeding resident in the southern and central Iraq; possibly in the northern Iraq. Winter visitor and passage migrant	Resident	Oct to Jun	Dec. 29	H, U
Cerylidae	Pied King Fisher	*Ceryle rudis*	Least concern	Widespread Breeding resident in wetland and water courses	resident	Oct to Jun (Dec* and Jan*)	Dec and Jan 500 - 542	UN, ON, FF, NY
Meropidae	Blue-cheeked Bee-eater	*Merops persicus*	Least concern	Breeding, summer visitor to northern and eastern Iraq,	Passage Migrant	Oct, Nov, and Apr	Apr. 28	M

				widespread passage migrant				
	European Bee-eater	*Merops apiaster*	Least Concern	Breeding summer visitor to northern and eastern Iraq; widespread passage migrant	Passage Migrant	Apr	Apr. 8	M
Alaudidae	Eurasian Hoopoe	*Alaemon alaudipes*	Least Concern	Widespread breeding resident in the western, central and southern deserts	Passage migrant	Mar	Mar. 1	Not seen in the breeding season
Laniidae	Red-backed Shrike	*Lanius collurio*	Least Concern	Widespread passage migrant	Passage migrant	Oct and May	May. 52	M

	Isabelline Shrike	*Lanius isabellinus*	Least Concern	Passage migrant and winter visitor, more frequent in south and central Iraq	Passage migrant and winter visitor	Oct to Mar	Jan. 25	Not seen in the breeding season
	Turkestan Isabelline Shrike	*Lanius phoenicuroides*	-	Uncommon passage migrant	Passage migrant and winter visitor	Oct, Jan, Feb, and Apr	almost same number 1-2	M
	Lesser Grey Shrike	*Lanius minor*	Least Concern	Fairly widespread passage migrant	Passage migrant	May	May. 31	M
Oriolidae	Eurasian Golden Oriole	*Oriolus oriolus*	Least Concern	Breeding summer visitor to woodlands of northern Iraq; widespread passage migrant	Passage migrant	May	May. 1	M

Corvidae	Hooded Crow	*Corvus cornix*	-	Uncommon breeding resident in northern Iraq	Winter visitor	Dec, Feb, and Mar	Feb. 5	Not seen in the breeding season
	Mesopotamian Crow	*Corvus capellanus*	-	Breeding resident of the plains and date orchards of southern and central Iraq; also found in stable and floating reedbeds of the southern marshes	Winter visitor	Dec and Mar	almost same number 1-2	Not seen in the breeding season
Alaudidae	Crested Lark	*Galerida cristata*	Least Concern	Widespread breeding resident	Resident	Oct to Jun	Oct. 32	T, H,A
Pycnonotidae	White -eared Bulbul	*Pycnonotus leucotis*	Least Concern	Widespread breeding resident in woodland groves, especially	Resident	Nov to Feb	almost same number 2-4	Not seen in the breeding season

				palm, in central, western , southern and northeast Iraq; appears to be spreading north as now found in northern areas where absent in 1940s				
Hirundinidae	Sand Martin	*Riparia riparia*	Least Concern	Breeding summer visitor, mainly along major river courses; passage migrant	Summer visitor and possible breeds	Mar to Jun	Apr. 54	H, U
	Barn Swallow	*Hirundo rustica*	Least Concern	Fairly widespread breeding summer	Passage migrant and breeding	Feb to Jun	Apr and May 35-38	ON, B, T, H

				visitor; widespread passage migrant; very few winter in southern Iraq	summer visitor			
Sylviidae	Willow Warbler	*Phylloscopus trochilus*	Least Concern	Widespread passage migrant	Passage migrant	Apr	Apr. 1	M
Phylloscopidae	Common Chiffchaff	*Phylloscopus collybita*	Least Concern	Widespread passage migrant and winter visitor	Passage migrant and winter visitor	Nov to Apr	Jan. 48	Not seen in the breeding season
Acrocephalidae	Basra Reed Warbler	*Acrocephalus griseldis*	Endangere d	Breeding summer visitor to the extensive reedbeds of the Southern marshes and recently discovered further north in the marshes of	Summer visitor and breeds	Apr, May, and Jun	Jun. 66	NY, NE, FF, ON, UN

				central Iraq and at one site in Western Iraq. Endemic species.				
	Great Reed Warbler	*Acrocephalus arundinaceus*	Least Concern	Rather local breeding summer visitor to wetlands and water course with reedbeds throughout Iraq; also a widespread passage migrant; birds recorded in the southern marshes in early February maybe	Passage migrant and breeding summer visitor	Oct, Nov, Apr, May, Jun	May. 57	NE, ON, UN

				overwintering or early migrants.				
Sylviidae	Sedge Warbler	*Acrocephalus schoenobaenus*	Least Concern	Passage migrant; found at one riverine site in breeding season in northern Iraq	Passage migrant	Nov, Apr, and May	almost same number 1-2	M
	Eurasian Reed-Warbler	*Acrocephalus scirpaceus*	Least Concern	Passage migrant with one proven record of breeding in the southern marshes. The status of this species has been complicated by the earlier confusion with Basra Reed Warbler.	Passage migrant	Feb and May	Feb and May 1-2	M, H

				Many early references to Reed Warbler probably referred to Basra Reed Warbler				
Cisticolidae	Graceful Prinia	*Prinia gracilis*	Least Concern	Widespread breeding resident in central and southern Iraq, very local in North and northeast Iraq	Resident and breeds	Oct to Jun	May. 104	ON, UN, P,T, B
Leiothrichidae	Iraq Babbler	*Turdoides altirostris*	Least Concern	Breeding resident in reedbeds, mainly along the Tigress and Euphrates Rivers, and extending its	Resident and breeds	Oct to Jun	Apr. 58	ON, B, H

				range northwards along the later. Endemic, thought now recorded along the Euphrates in Syria and South Turkey				
	Afghan (Common) Babbler	*Turdoides caudata*	Least concern	Breeding resident in Southern, Western, and Central Iraq, mainly in arid areas with scrub	Resident	Jan, Feb, Mar, and May	almost same numbers 16-18	U, H
Sturnidae	Common starling	*Sturnus vulgaris*	Least Concern	Very local breeding resident in open wood land in the North of Iraq	Winter visitor	Nov to Mar	Feb. 549	Not seen in the breeding season

				, widespread winter visitor				
Turdidae	Song Thrush	*Turdus philomelos*	Least Concern	Irregular winter visitor	Winter visitor	Jan	Jan. 1	Not seen in the breeding season
	European Robin	*Erithacus rubecula*	Least Concern	Fairly widespread winter visitor	Passage migrant and winter visitor	Nov, Dec, and Jan	Dec. 5	Not seen in the breeding season
Muscicapidae	Bluethroat	*Luscinia svecica*	Least Concern	Fairly wide spread passage migrant and winter visitor	Passage Migrant and winter visitor	Nov to Feb	Same number. 1	Not seen in the breeding season
Muscicapidae	Rufous-tailed Scrub-robin	*Erythropygia galactotes*	Least Concern	Fairly widespread breeding summer visitor , but absent from western Iraq; passage migrant	Passage migrant	Nov	Nov. 1	Not seen in the breeding season

	Common Redstart	*Phoenicurus phoenicurus*	Least Concern	Local breeding summer visitor to woodlands in north Iraq with both *Phoenicurus* and *samamisicus* recorded; otherwise wide a widespread passage migrant	Passage migrant	Apr	Apr. 1	M
	Whinchat	*Saxicola rubetra*	Least Concern	Passage migrant, references to past winter records have not been confirmed in recent surveys	Passage migrant	Nov and May	same number 4-5	M

	Common Stonechat	*Saxicola torquatus*	Least Concern	Fairly widespread passage migrant and winter visitor	Passage migrant and winter visitor	Dec and Jan	same number 3	Not seen in the breeding season
Muscicapidae	Northern Wheatear	*Oenanthe oenanthe*	Least concern	Very local breeding summer visitor to mountain slopes and foothills in northeast; widespread passage migrant	Passage migrant	Mar and Apr	Same number 6-8	M
Passeridae	Black-eared Wheatear	*Oenanthe hispanica*	Least Concern	Breeding summer visitor to northern hilly country; widespread passage migrant	Passage migrant	Apr	Apr. 1	M

	House Sparrow	*Passer domesticus*	Least Concern	Widespread breeding resident	Resident	Oct to Jun	Oct. 221	NY, NE, FF, ON, UN,
	Spanish Sparrow	Passer hispaniolensis	Least Concern	Local breeding resident in North and Central Iraq; widespread winter visitor	Winter visitor	Nov, Dec, Jan, Feb, and	Dec. 30	M
	Dead Sea Sparrow	*Passer moabiticus*	Least Concern	Local breeding resident found especially, along major water course, widespread in winter	Resident	Oct, Nov, Dec, Feb Mar, Apr, and May	Nov. 450	U, H, B
Motacillidae	Yellow Wagtail	*Motacilla flava*	Least Concern	Widespread passage migrant.	Passage migrant	Mar, Apr, May	Apr. 86	M

	Citrine Wagtail	*Motacilla citreola*	Least Concern	Uncommon passage migrant and winter visitor	Passage migrant and winter visitor	Oct, Jan, Feb, Mar, Apr	Mar and Apr. 4	M
	White Wagtail	Motacilla alba	Least Concern	Local breeding resident in northern Iraq; widespread passage migrant and winter visitor	Passage migrant and winter visitor	Oct to Apr Dec and Jan	Dec. 134	M
	Water Pipit	Anthus spinoletta	Least Concern	Probably breeds as found in suitable breeding habitat at mountain site in northeast Iraq in Jun, 2011; Fairly widespread passage	Passage migrant and winter visitor	Oct to Apr	Nov. 26	M

				migrant and winter visitor				
Emberizidae	Corn Bunting	*Emberiza calandra*	Least Concern	Breeding resident in Northern farmland and open woodland; fairly widespread passage migrant and winter visitor	Winter visitor	Jan	Jan. 1	Not seen in the breeding season
	Ortolan Bunting	*Emberiza hortulana*	Least Concern	Breeding summer visitor to the hills of northern Iraq widespread passage migrant	Passage migrant	Apr	Apr. 1	M
	Reed Bunting	*Emberiza schoeniclus*	Least Concern	Uncommon winter visitor	Winter visitor	Feb	Feb. 1	Not seen in the breeding season

Chapter 3. Status of Euphrates Soft-shelled Turtle *Rafetus euphraticus* in the Iraqi Central Marsh

Abstract

The Euphrates softshell turtle *Rafetus euphraticus* is classified as Endangered on the IUCN Red List and is thought to have undergone large, recent population declines. Species information in Iraq is limited to a few rapid surveys with little detailed information on breeding and distribution. The study aimed to record basic reproductive parameters and counts of Euphrates softshell turtle within the Central Marsh (CM). Transect line methodology (150-200 m fixed-width) was used to record the distribution of Euphrates softshell turtles within the study site and nine surveys were carried out from October 2013 to June 2014. Only turtles outside of the water were recorded as surveys were from a motorized canoe and so it was not possible to survey turtles in the water accurately; thus our counts are likely to underestimate true numbers. The total number of nests and eggs found were five and 34 respectively. The mean nest diameter ± SD was 7.8 ± 0.77 cm and the average diameter ± SD of the spherical eggs was 2.63 ± 0.14 cm. The highest counts were in the breeding season (April, May, and June). Simple extrapolation of our counts to the entire CM suggested a maximum population size of 212 - 283 individuals/141,615 ha. Results from our surveys suggest the start of breeding season for *Rafetus euphraticus* in the CM is two months earlier than in Iran and Turkey.

3.1 Introduction

The Euphrates softshell turtle *Rafetus euphraticus* (Figure 3.1) is classified as Endangered on the IUCN Red List and is thought to have undergone large, recent population declines (European Reptile & Amphibian Specialist Group, 1996; Garstecki and Amr, 2011). The turtle is distributed across Iraq, Syria, Turkey, and Iran (Ghaffari, Taşkavak and Karami, 2008). Although Iraq is thought to contain the largest number of suitable sites for the species (Nature Iraq, 2017), there is a lack of information within the country on this species (Ihlow *et al.*, 2014). The first published observations in Iraq (after anecdotal records in the 1960s) were in 1992 from the Euphrates River (Stadtlander, 1992).

Figure 3.1. Photograph of the Softshell Turtle in Iraq's Central Marsh.

The species was subsequently recorded in Iraq from 2005 onwards during KBA (Key Biodiversity Area) surveys in nineteen sites all over Iraq; two sites in the Kurdistan region and Mosil (Stadtlander, 1992; eight sites in the central part of Iraq and nine sites in the south of Iraq; Nature Iraq, 2017; Figure 3.2). However, these surveys were rapid and more intensive surveys at finer spatial scales are needed to obtain a more accurate understanding of the species' distribution and conservation status. Similarly, while some of the turtle's breeding ecology and conservation status have been described within the turtle's other range countries (Ghaffari *et al.*, 2013), there have been no such studies within Iraq.

Like many reptiles the Euphrates softshell turtle makes use of a wide range of wetland habitats. They often use shallow calm water but typically such areas are adjacent to deep fast-flowing areas (Taşkavak *et al.*, 2016). They are most likely to be observed by humans when they bask on river banks. The species is mainly active during the day, but some nocturnal activity also occurs (Taşkavak *et al.*, 2016). In parts of its range it is infrequently seen during the winter, likely due to the lower temperature (Taşkavak *et al.*, 2016),

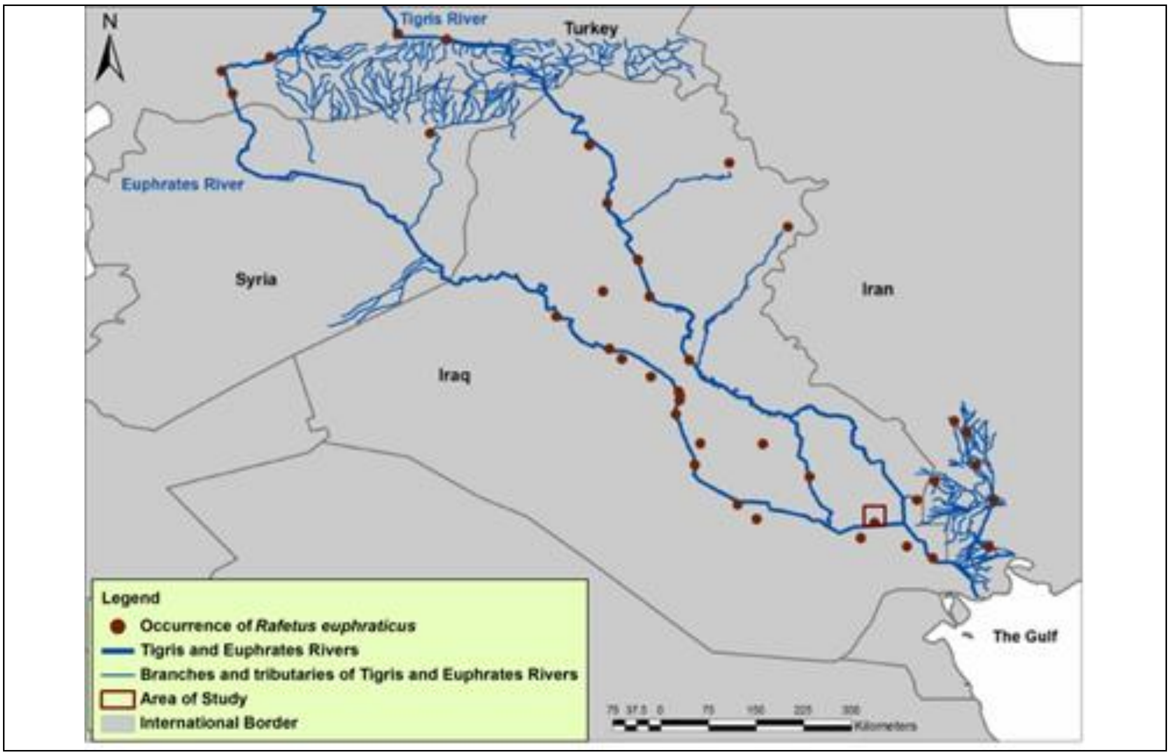

Figure 3.2. The regional distribution of *Rafetus euphraticus* across the Mesopotamian Rivers basin in Turkey, Syria, Iraq, and Iran (area 950,876 km2). Each dot gives the location of sites where the Softshell turtle has been recorded based on the published literature. Data were obtained from Nature Iraq and The Global Biodiversity Information Facility (GBIF Secretariat, 2016), and were manipulated using ArcGIS software (version 10.2.1).

Our study focuses on the Central Marsh (CM) in the south of Iraq, which has been identified as a potential stronghold for the species based on habitat suitability (Nature Iraq, 2017). The CM (Figure 3.3) is one of the three largest wetlands in Iraq formed as part of the Tigress-Euphrates river complex. The CM formerly covered around 300,000 hectares, but was almost totally drained following the 1991 uprisings in Iraq and has since been re-flooded in 2003-4. While the CM is the first national park in Iraq (declared in July 2013 under the name Mesopotamian National Park of MNP; Pearce, 2013; Ministry of Environment, 2014), the area is used extensively by humans. Studies from Iran and Turkey have shown that habitat modifications, water pollution and persecution by fishermen are the main threats to the survival of the turtle and this may also be the case in the CM (Taşkavak, Atatur and Smith, 1995; Ghaffari, Taşkavak and Karami, 2008). However, whether the softshell turtle faces similar threats in the CM is not fully known, in part because detailed surveys have not yet been undertaken in the area. Similarly, a full understanding of the turtle's breeding ecology and conservation in the CM is lacking. This dearth of information could have important conservation ramifications for the softshell turtle in the CM. For example, the rising human population of nearby Chibayish city is predicted to increase human activities in the study site, and scarcity of water in the Euphrates River could negatively affect wildlife. Knowing where the turtle is distributed in relation to threats and whether its nesting grounds are vulnerable to such threats could help conserve the species and to create a more resilient population for the future. Given the lack of scientific information on the Euphrates softshell turtle *Rafetus euphraticus* in Iraq and the likelihood of their occurrence due to suitable habitat, we aimed: (1) to make counts of Euphrates softshell turtles in the CM and to record basic reproductive parameters; (2) to calculate simple population estimates of the species with the CM by simple extrapolation of count data. These results are discussed in relation to both the CM and Iraq as a potential stronghold for the softshell turtle population.

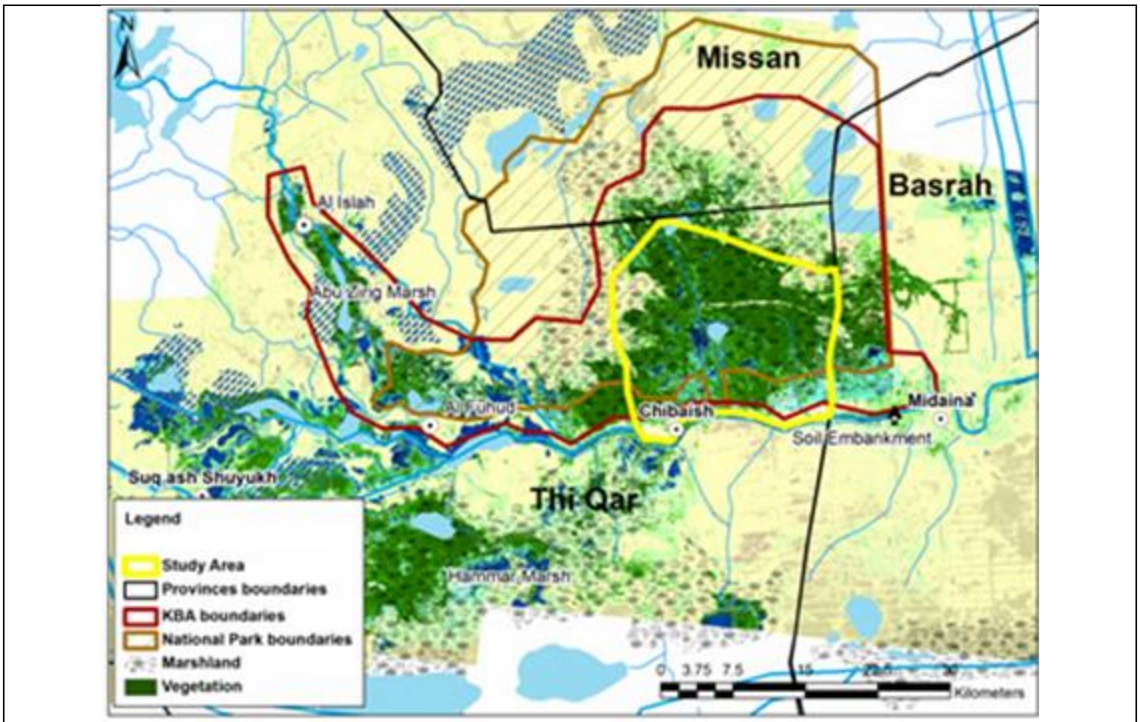

Figure 3.3. Detailed map of the study area (enclosed by the line in yellow). Boundaries of the protected area and KBA are also shown by the brown and orange lines respectively.

3.2 Materials and Methods

3.2.1 *Site Description*

The study site is 40,000 hectares in area and is part of the CM (or MNP) that is located downstream of the Mesopotamian Tigress and Euphrates rivers (Figure 3.3). The total extent of the MNP is 141,615 hectares and is located between three provinces Thi–Qar from the south and west, Basra province from the east, and Missan province from the north. The MNP was chosen to be a protected area for habitat and species management for natural conservation according to IUCN criteria IV (Alwash *et al.*, 2009). The area was rapidly monitored for five years between 2005-2010, and defined as a KBA (Key Biodiversity Area) and IBA (Important Birds Area) site (Nature Iraq, 2017). The area has four vegetation forms (Hamdan *et al.*, 2010): submerged aquatic (*Ceratophyllum demersum, Myriophyllum verticullatum, Najas marina, Potamogeton crispus, Potamogeton lucens, Potamogeton nodosus, Vallisneria spiralis*), floating-leaved aquatic (*Lemna minor, Nymphoides indica, Salvinia natans*), herbaceous tall emergent (*Phragmites australis, Schoenoplectus litoralis*, and *Typha domingensis*) and herbaceous low emergent (*Copa monnieria, Jussiaea repens, Polygonum salicifolium, Ranunculus sphaerospermu*). To aid management, we sub-divided the study area into three zones (Figure 3.4). We did this based on similarities in the type of human activity that occurred there (e.g. fishing, reed cutting and milk production by water buffalo), the intensity of water buffalo grazing and the dominant type of vegetation. This classification was made by visual inspection of the CM and was descriptive only (based on qualitative impressions made during the survey work). Zone one started from the south in the Euphrates River, with zones two and three extending north inside the national park. Zone one had the most human activity, grazing of water buffalo and *Typha domingensis* was the dominant plant species. Zone two had intermediary levels of human activity and water buffalo grazing with *Typha domingensis* and *Phragmites australis* the dominant plant species, and zone three had the least amount of human activity and grazing with *Phragmites australis* the dominant plant species.

3.2.2 *Field Surveys of Euphrates Softshell Turtle Rafetus euphraticus*

Transect line methodology (150-200 m fixed-width) was used to record the distribution of the Euphrates softshell turtle (outside water) within the study site (Sutherland, 2006). A motor canoe was used to carry out all surveys (see photo in Appendix 3). Only turtles outside of the water (e.g. basking) were recorded from our surveys. This was because turtles were only visible when in the water when they were immediately (within a few meters) of the canoe and so coverage was only within a few meters of the canoe. Although this survey method will probably underestimate turtle numbers it enabled coverage of a much larger area. Three longitudinal water transects (each 30 km in length) were selected to encompass parts of the nine water channels that feed the area from the Euphrates River in the south of the MNP through Chibayish city to the North of the site. The first transect started from Abo Sobat channel in the middle of the main water channels, the second transect started from the last channel in the eastern side of the park in Al Kinziri village and the third transect started from the first channel in Al Hamrawia (Al Moajed village) in the West side of the MNP (Figure 3.4). Each of the three transects crossed each zone (Figure 3.4). Nine surveys were carried out to survey the Euphrates softshell turtle in the CM from October 2013 to June 2014 (for exact dates see Chapter 2). An additional ten km-long transect (transect four) in zone two was added to observe and monitor the breeding season of the turtle in April, May, and June, 2014 (Figure 3.4), providing a total transect network of 100 km for those months. This transect was added because there were no other terrestrial areas within the CM during the time of surveying where the turtle could have laid its eggs. Therefore, it was vital to visit this area during the breeding season. Additional time was included in the survey visits to incorporate the extra time needed to cover the fourth transect. Thus, the uneven survey effort across the entire survey period could have biased our population estimates which should thus be viewed with caution.

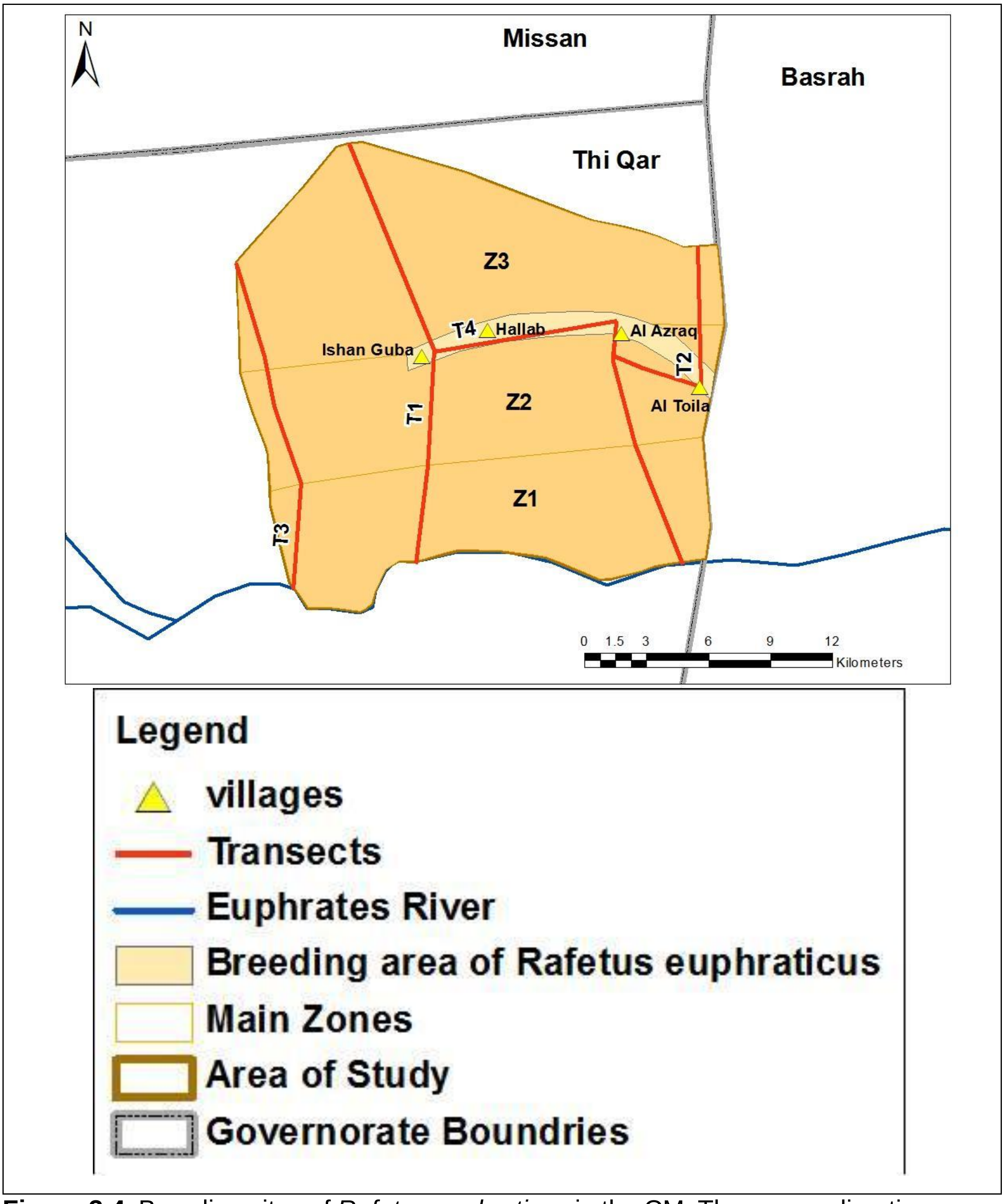

Figure 3.4. Breeding sites of *Rafetus euphraticus* in the CM. The survey direction is northwards.

Three days were spent in the area in each survey (one day/transect), and six – eight hours per day were spent inside each transect. All field observations were collected in the morning starting from the river in zone one and finished in the afternoon at the end of zone three (we started our surveys early in the morning and returned back to the starting point in the afternoon). However, the precise time we conducted surveys differed between summer and winter surveys (5:30 – 12:30/13:30 in the summer, and 7:00 – 14:00/15:00 in the winter). Our sampling design was constrained by safety considerations and logistical difficulties, which made it impossible to conduct sampling in zone three in the morning. A Canon 7D camera with Sigma lens 135 x 400 and Canon lens 100 x 400 and 8 x 42 binoculars were used to observe the turtles up to 150 - 200m from the transect line, a tape measure was used to measure nest and egg dimensions, and a Garmin GPS device was used to draw the three transects and record locations of turtles and their nests. We recorded the number of turtles, the number of nests, egg dimensions and the soil composition of each nest. Given the turtle's poor conservation status, we did not disturb the nests and were not able to record actual clutch size (we did not want to pick up eggs in order to see how many lay beneath) only an estimate from visual observation. Soil samples were analysed by the Centre of Environmental Research, University of Technology in Baghdad.

3.2.3 *Calculating the Population Density of the Softshell Turtle*

To estimate the population density of the Euphrates softshell turtle *Rafetus euphraticus*, we counted the number of turtles (individuals outside water) within 150-200m either side of each transect (total width of 300-400 m) and then used the following equation to provide estimates for each survey month: $D= n/ (L \times W)$ where: D = density, n = total number of animals detected, W = width of transect and L = length of transect.

Although this is a simple extrapolation from our count data we have presented this information as there is a dearth of data on population numbers of this species and so these estimates act as the 'best' estimates to date albeit with associated errors. We used the equation identified for calculating population density estimates for fixed-width line-transects to provide density estimates for the total area of land surveyed (Sutherland, 2006). To provide a maximum population estimate for the softshell turtle within the CM, these results were then extrapolated. The extrapolation was undertaken by multiplying the population density from our surveys to the entire area of the CM. There are several caveats with this value: (i) we assume that the habitat within the CM was relatively homogenous but, of course, this is a simplification; (ii) counts were only of turtles outside the water and so inevitably many turtles in the water will be missed; (iii) we did not cover the entire study area but sampled transects within it. We caution that in reality the turtle population could be more accurately surveyed with other methods (e.g. mark recapture methods to enable resighting probabilities to be estimated along with 'true' survival).

3.3 Results

3.3.1 *Field Surveys of Euphrates Softshell Turtle Rafetus euphraticus*

Records of the Euphrates softshell turtle *Rafetus euphraticus* were unevenly distributed across the nine month period when surveys took place. Turtles outside of the water were recorded in only four of the nine surveys. Two turtles were found in October in T3, Z1, but no turtles were found from November to March. Most records came from the April, May, and June surveys. Five individuals were recorded in April (two adults and one dead juvenile that was 11 cm in length in T1, Z2 and two adults in T2, Z2), six individuals were recorded in May (One adult and one juvenile that was 22 cm in length in T2, Z1, Two adults in T2, Z2, and Two adults in T1, Z2), and two adults in June. All records from these three months were in transects one and two (Figure 3.5).

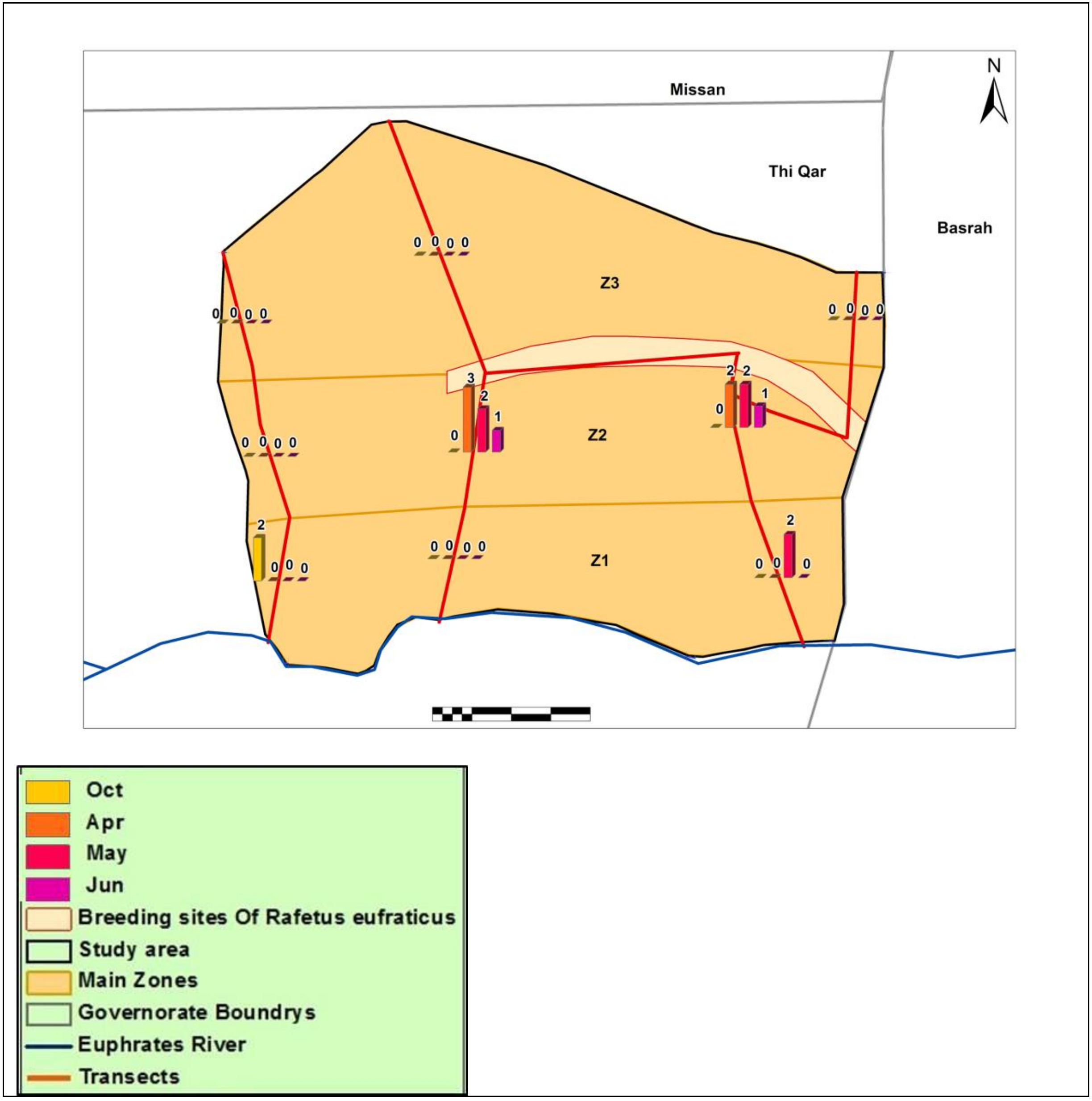

Figure 3.5. Monthly individual records of *Rafetus euphraticus* in the CM. Surveys from October, 2013 to June, 2014.

The additional survey in transect four (T4) showed that zone two, and especially the area located between transects one and two near to small local villages (Ishan Guba, Halab, Al Azraq, and Al Toila), contained the largest numbers of breeding turtles (Figure 3.4 and Figure 3.6 in the Appendix 3 for photographs of each zone). The total number of nests and eggs found were five and 34 respectively. The mean nest diameter ± SD was 7.8 ± 0.768 cm (n = 5) and the average diameter ± SD of the spherical eggs was 2.63 ± 0.141 cm (n = 34). The smallest number of nests was in June and the largest was in May, while the smallest number of eggs was in April and the largest was in May (Table 3.1). These observations are supported by photos of the turtle, nests and eggs in the field (Figure 3.7 in Appendix 3).

Table 3.1. Numbers and distribution of *Rafetus euphraticus* nests in the CM. Note that nests with star * are independent i.e. different nests in each month.

Villages		**April 2014**	**May 2014**	**June 2014**
		Number of nests	Number of nests	Number of nests
Ishan Guba	T1-zone 2	2*	2	2
Halab	T1-zone 2	1*	1	0
Al Azraq	T2-zone 2	0	1*	0
Al Toila	T2-zone 2	0	1*	0
Total in the CM		3	5	2

All nests and eggs were recorded in zone two of the study area and were focused in one sector (transect four). Nesting was first recorded in the middle of April and the highest number of eggs was recorded in May (see list of survey exact dates in the Appendix 3). The turtles nested in the soil on the bank of the marsh's water. The soil composition of the nesting sites in the CM (collected from soil data at nest locations) was 18.6% sand, 35% clay and 46.4% silt as averaged across all the samples (n = 4).

3.3.2 *Estimation of Population Density from Counts of Softshell Turtle*

Turtle counts varied between monthly surveys and seasons: there were no records in the winter, while the highest density was recorded in the breeding season (April, May, and June; Table 3.2). The maximum population size (based on simple extrapolation – see methods) likely to be sustained by the CM is 212 - 283 individuals.

Table 3.2. Estimates of Euphrates soft shelled turtle densities in the CM (MNP) within a fixed-width distance of 150 - 200 m (total width = 300 - 400 m) from the transect lines (based on simple extrapolation). Note: we have provided two estimates based on whether the minimum (150m) or maximum (200m) transect width is used to extrapolate turtle numbers.

Survey Month	Number of Individuals / ha x 10^{-4} in distance 150m	Maximum population size in the Central Marsh (individuals / 141,615 ha) in distance 150m	Number of Individuals / ha x 10^{-4} in distance 200m	Maximum population size in the Central Marsh (individuals / 141,615 ha) in distance 200m
October	7.4	104.9	5.5	78.7
April	16.7	236.0	12.5	177.0
May	20.0	283.2	15.0	212.4
June	6.7	94.4	5.0	94.4

3.4 Discussion

Previous work in Iraq recorded the species in 28 sites along the Tigress and Euphrates rivers and their branches and tributaries. The species has been recorded in 19 KBA sites across Iraq between 2005 – 2010 (an area of 1,231,444 ha; Nature Iraq, 2017), with 55 individual records in the Euphrates River from Faloja to Hammar Marsh (c. 400 km) in 1992 (Stadtlander, 1992). Our study is the first to estimate softshell turtle densities in Iraq and suggests that the CM could be an important site for the softshell turtle in the Iraq, with a maximum estimated population size of 212-283 individuals. Given this result, prioritizing the CM for future conservation of soft-shelled turtle in Iraq is recommended (Ghaffari, Taşkavak and Karami, 2008; Ihlow *et al.*, 2014).

The breeding and appearance of *Rafetus euphraticus* is highly seasonal (Ghaffari, Taşkavak and Karami, 2008). April to October is thought to be the key time to survey for the turtle and it is thought to prefer areas with shallow and calm water, alluvial soil, sandy banks, certain vegetation types (e.g. *Tamarix* sp., *Populus euphratica*) and an abundance of fish (e.g. *Barbus* spp., *Chalcalbrnus* sp. and *Cyprinus carpio*; (Taşkavak, 1999; Biricik and Turğa, 2011; Ghaffari *et al.*, 2013). Our results support the idea of breeding at these times, as no turtles were observed in CM during the winter survey from October to March, while the appearance and nesting period was between April and June.

Whilst it is possible that we missed recording turtles in colder months (as they were less likely to be out of the water), we still checked for the presence of nests on land (land was checked for nests on each survey visit throughout the survey period) and none were found in those months. There were some differences between our results and those reported for turtle populations in other countries in its range. For example, the start of the breeding season in Iraq was slightly earlier than elsewhere middle of April in the CM: in Iran breeding begins in June and July (Ghaffari, Taşkavak and Karami, 2008) and this is also true for Turkey (Biricik and Turğa, 2011). Also, whereas we found turtle nests located in bare soil in Iraq, they are reported to be found amongst vegetation in Iran with a soil composition of 77% silt (Ghaffari *et al.*, 2013) and are found in pure sand in Turkey (Biricik and Turğa, 2011). The eggs found in the CM were also slightly smaller than those elsewhere 26.30 mm ± 10.41 (SD) in the CM: the mean diameter of turtle eggs in Iran is 28.7 mm and in Turkey it is 23.3 ± 0.13 (SD) mm (Taşkavak, 1998) and 29.47 mm ± 0.29 (SD; (Biricik and Turğa, 2011).

Our results come with some caveats. First, due to safety issues we were not able to randomize the direction that we sampled each transect. This means that the detectability of the turtle within each zone may be different (e.g. turtles may be more sluggish in the morning), making it difficult to disentangle the effect of detectability from underlying abundance. Similarly, we have not sought to examine detectability and its effects on the turtle's population density estimates in a detailed way. Using other methods such as mark-release-recapture would provide more accurate population estimates by estimating re-sighting probabilities (e.g. we may have been recording the same animal many times although every effort was made to attempt to avoid double counting of the same individual). Second, it is important to repeat our surveys within the CM over a longer time period to identify whether the results we report here are consistent between years (and also later in the summer period from July-September). Finally, the population estimates that we report for the CM are estimates only and in reality are likely to be altered by biases of recording only turtles outside of the water, extrapolations of counts across the whole CM (which assumes a homogenous area).

Our surveys recorded the highest densities of the species close to Al Bagdadia (Ishan Guba village) in transect one zone two (Figure 3.4). This area is characterized by open water with dominant vegetation including *Typha domingensis* and *Phragmites australis*, with frequent records of the invasive fish species *Tilibia zilli* (Nature Iraq, 2017). The turtles mainly used the area along transect four for nesting despite being very near to local houses. The area in transect four is historically considered the highest land in the middle of open water in the CM, and it is crowded during the breeding season, with many other species (e.g. reptiles, mammals, birds, and amphibians) being recorded (Fazaa, N.A., unpublished). Thus, observations from our study suggest the species is able to tolerate a degree of disturbance.

We recommend the following management actions:

1. Undertake a robust survey to estimate the population size and its distribution within the CM.
2. Protect the ‘hot spot’ in zone two of the CM.
3. Investigate ways of enhancing connectivity between the Euphrates and CM-Tigress in light of soil embankment.
4. Control the threats of hunting and pollution within the CM.

3.5 Appendix 3

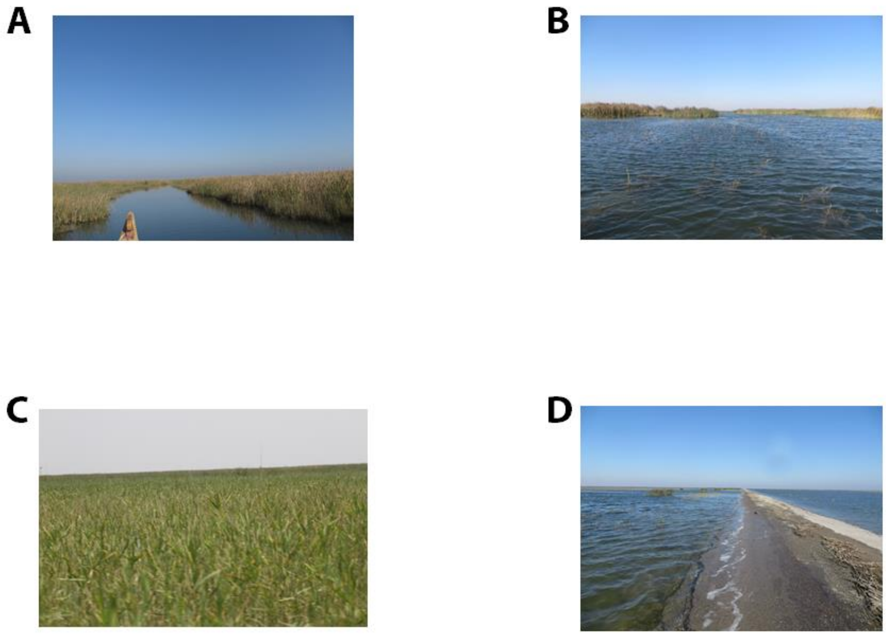

Figure 3.6. Appendix. Photographs of Central Marsh: A = zone 1, B =zone 2, C= zone 3, and D= the paved road in the middle of the NP.

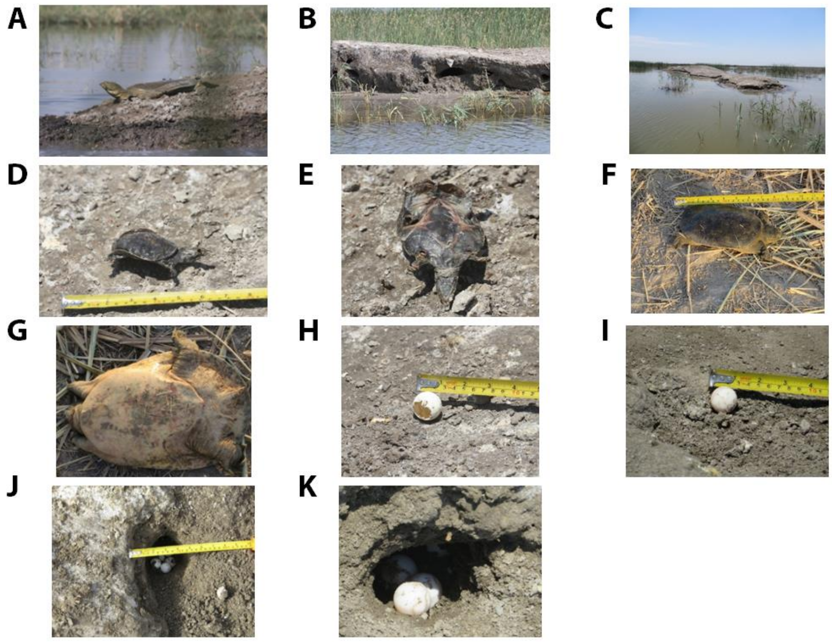

Figure 3.7. Appendix. Photos of Euphrates softshell turtle and its breeding habitats: A = Rafetus euphraticus, B and C = breeding sites of Rafetus euphraticus in transect 1, zone 2, D and E = dead juvenile (11 cm long), F and G = juvenile (22 cm long), H and I = eggs of *Rafetus euphraticus* in the CM and J and K = nests of *Rafetus euphraticus* in the CM.

Chapter 4. Evaluation of the ecosystem services of the Central Marsh in Southern Iraq

4.1 Introduction

Ecosystems services are vital for humans and a healthy environment is important for wildlife (Sukhdev *et al.*, 2010); however, there is no one universally accepted method used to value and define ecosystem services. The benefits people can obtain from nature has sometimes been defined as ecosystem services (e.g. healthy ecosystems can provide food, fresh water, protection from extreme weather, climate regulation, waste and pollutant filtration, and clean air and soil; Millennium Ecosystem Assessment, 2005; Carpenter *et al.*, 2006; ICSU-UNESCO-UNU, 2008).

Despite their importance, the MEA has indicated that unprecedented changes have been made to the planet's ecosystems in the last 50 years. As a result, 60% of global ecosystems were examined in the 2005 MEA to assess the health of the planet's ecosystems, the ability of the ecosystems to provide for the needs of current and future generations, and what we can do to protect and conserve natural systems. As a result, the importance of valuing ecosystem services has increased significantly in the last decade, and countries have been encouraged to include such services in national budgets and policies (e.g. Aichi target number 14, which focuses on maintaining and enhancing ecosystem services; Rubec, Alwash and Bachmann, 2009; Costanza *et al.*, 2014). Moreover, the World Business Council for Sustainable Development (WBCSD) has adopted ecosystem services as a supportive concept for the world's economy (WBCSD, 2017), and there has been a surge of recent interest by the academic community to explain, analyse, and predict the value of the ecosystem services (e.g. Boerema *et al.*, 2017; Costanza *et al.*, 2017; Scholtens, 2017). Although ecosystem services can be valued through interactions between natural capital (world stock of natural assets), human capital (presence of people in the system), social capital (the communities), and built capital (built environment; Costanza *et al.*, 2014), most previous studies have valued ecosystem goods and services within and across biomes (e.g. sixteen biomes in Costanza and Folke (1997), eleven biomes in De Groot *et al.* (2002), and ten biomes in De Groot *et al.* (2012)).

Broad scale evaluations at the biomes level provides a general assessment of global ecosystem services, which uses sophisticated modelling approaches (Sukhdev *et al.*, 2010; Costanza *et al.*, 2014). While assessments on this scale are important, placing a value on ecosystem services at the site level is crucial to support local and national policies, especially in light of the huge changes that have occurred to natural systems and the accelerating impact of climate change (Peh *et al.*, 2013). Enhancing and embedding ecosystem services in local and national policies requires engaging stakeholders and decision-makers and sharing data when assessing the services (Edwards and Gibeau, 2013). Thus, a toolkit for the rapid assessment of ecosystem services at sites of biodiversity conservation importance (Toolkit for Ecosystem Services Site-Based Assessment - TESSA) was adopted by eleven organizations under the umbrella of the Cambridge Conservation Initiative (Peh *et al.*, 2013).

TESSA was designed as a toolkit to assess ecosystem services at the site level with less cost, effort, resources, and technical knowledge required. Similarly, TESSA was designed to guide local non-specialists to come up with a rapid estimate of the value of ecosystem services, while being flexible enough to allow users to develop and modify the assessment methods according to local context and the availability of experts and resources. The toolkit helps the user to identify which services to assess, what data are needed to measure them, what methods or sources can be used to obtain the data, and how to communicate the results for better biodiversity conservation. The toolkit is designed as a decision key, rather like a biological key for identifying species. It leads the user through a series of steps or questions, so that the user learns along the way. The toolkit provides specific guidance on implementing practical methods for assessing some of the services that are likely to be most important to the range of stakeholders in each ecosystem or habitat. These methods range from collecting new data from local field surveys or stakeholder workshops to using existing datasets or published studies to extract site-relevant information. In every case, it is expected that the methods and guidance will be adapted to suit the local context. We designed our study according to TESSA with modifications according to the circumstances of our selected site, the Iraqi Central Marsh.

The Euphrates River meets the Tigress River after passing Chibayish city in Basra province. The creation of the soil embankment effectively truncates the Euphrates River, which never happened in the past. If water levels are low enough, the embankment can prevent the Euphrates River from meeting the Tigress River and makes the CM the terminal site for all of the water discharged by the Euphrates, containing high concentrations of different pollutants from the upstream provinces. The impact of the soil embankment on the CM's local people and ecosystem services has not been examined by the Iraqi government or scientists. Thus, due to a lack of information about the impact of the soil embankment and water scarcity on the CM we aim to aid the creation of a management plan for the NP and CM by placing a value on the CM's main ecosystem services at the site level. Undertaking such a study could help policy makers and local people have a better understanding of the effects of extreme water scarcity events in the Euphrates River on the CM. In addition, it will provide an estimate of the economic value that could be lost from the CM in the future owing to an increased frequency in droughts that may result from climate change.

4.2 Materials and Methods

4.2.1 *Valuing the CM's ecosystem services*

According to the TESSA methodology, the first step in an assessment is to: i) define the site based on its biological importance and perceived threats; ii) explore policy content; and iii) identify ecology, sociological and political issues. Next, rapid appraisal should be undertaken to: i) identify and engage stakeholders; ii) identify habitats and drivers of change; and iii) identify services and beneficiaries. Once this is conducted, plausible alternative states are identified and appropriate methods are selected in order to assess relevant services under current vs. alternative states. Data are then acquired and analysed and the results are communicated to various stakeholders. Given that the CM site is already well defined in terms of biological importance (see Chapters 2 and 3) and perceived threats (Chapter 1), we first sought to engage with local stakeholders.

Involving local people in the design of data collection methodologies regarding ecosystem services helps to identify focal services and provide a clear image of the relationship between local people and the site (Peh *et al.*, 2013). Participatory Rural Appraisal (PRA) methods have been widely used to involve rural people in local projects to enhance local planning and strategies (Chambers, 1994c). This method was conducted in our study to identify focal socio – economic activities in the study area and to orient our data collection methods. Data in this method was extracted directly from the local people, because there is no available data regarding natural systems and ecosystem services/goods in Iraq. Participatory mapping, modelling, and walking transects to collect data have been used worldwide and adopted by scientists, because they provide more factual results in comparison with other socio-economic methods (Chambers, 1994a, 1994b). Due to a lack of data regarding CM ecosystem services, a PRA semi-organized interview tool was used to collect data from the CM's local people, in which questions that did not have yes and no answers were prepared before the interview. Direct conversation with local people was used to answer the questions (questionnaire is shown in the Appendix 4 – Table 4.4). These questions were designed to enable us to identify the socio-economic issues surrounding the CM and to identify services provided to the local people by the CM. All interviews were conducted by a team of three people including Nadheer Fazaa and Mahdi Salih and Dhrgam Ali from the Chibayish office of Nature Iraq.

Analysis of the preliminary data collected using the PRA survey helped to inform our work and led us to design more precise and focused methods and questions to collect data on the key ecosystem services identified (Appendix 4, Table 4.4). Data on the trading of fish, harvested plants, water buffalo milk, fodder, and hunted birds were collected by conducting six - seven months of monitoring of local economic activities (from December 2013 and January to June, 2014). We divided the study site into three zones and three transects according to the local activities that were highlighted by the PRA survey (Figure 4.1). Four main economic assembly points (an economic assembly point is defined as a place where the trading of goods occurred) in zone one (two out of the four sites were located in zone one-transect one, one point was located in zone one-transect two, and one in zone one-transect three) were observed during the surveys period with between two-seven observations undertaken per month (minimum number of observations were 2 per month and maximum number of observations were 7 per month). For all the economic activities monitored, we calculated mean amounts of each resource traded within a typical day within the focal month. We then multiplied this daily output by the available working days within each month. We did this for each of the six survey months, before finally obtaining a monthly average output across the six months. We monitored the following economic activities:

Trading of water buffalo milk: the PRA survey highlighted there was economic activity involving the trading of water buffalo milk in Chibayish city. We identified there were a total of ten dealers who worked in zone one to buy and sell the milk. We monitored the economic activity of the dealers for six months. Three to five observations per month were conducted to record the daily volume of milk that was collected from local people by the ten dealers and sold to other provinces. There were 15-20 working days in a month. For each of our survey days, we calculated the total volume of milk sold by all dealers. We then calculated the mean amount of milk sold for a typical day within that month, which was then extrapolated to one month by multiplying this mean by 15 working days per month. Finally, we calculated the monthly value of milk trading in the area in USD by multiplying the extrapolated amount for one month by the price of milk per ton.

Trading of fish: the PRA survey highlighted there was economic activity involving the trading of fish in Chibayish city. One main economic assembly point was used in Chibayish city (transect one-zone one) to sell fish to other provinces and the resulting economic activity was monitored for six months in 2014 (three -

five observation per month). The local government bans fishing in the CM yearly from February 15th to April 15th. However, in reality, fishing fluctuated in this period and our observations suggested the ban is not well-enforced as local people who rely on fishing for their daily economy cannot stop the activity for two months (people are going daily for fishing during our survey time. However, the amount of fish is less and number of fishermen is less as well). We used a GLM in Minitab 17 to analyse the trading of fish and to calculate the monthly mean amount of fish traded and to identify the most traded fish species. The total value of trading fish in Chibayish city was calculated by multiplying the extrapolated mean amount of fish traded by price per ton during the survey time using the same methods as for the buffalo milk, which was then multiplied by 90 working days within 6 months.

Collection/trading of harvested plants: The economic trading of harvested plants was conducted in the four main assembly points within zone one. Local people (from Chibayish city near zone one) go inside the CM to cut plants daily and then sell them at noon at the main four assembly points in the city. We collected data three times in January, three times in February, five times in March, four times in April, and three times in May and June (please see the exact dates in the Appendix 4 – Table 4.5). We used a GLM in Minitab 17 to analyse plant data and to identify differences in plant cutting at the three transects, and to calculate the monthly mean harvested plants mass in tonnes, and calculate the total value of this mass in USD during the survey period. We estimated the monthly harvested plant mass by multiplying the survey mean (three – five observations/ survey) by 15 working days per month.

Trading of fodder: the PRA survey highlighted the economic activity of fodder trading in Chibayish city. We identified four dealers of fodder (by using PRA results) in the city (in zone one). Fodder is essential as additional food for water buffalo. Water buffalo normally graze in the CM during the day and are given fodder as additional food in the evening by the local people. Water buffalo graze in the marsh when the water temperature and quality is suitable for swimming and drinking, which means that grazing times during the day differ seasonally. We monitored the economic activity of the four dealers for six months. Three to five observations per month were collected to record the daily amount of fodder sold to the local people as food for the buffalo. The mean daily amount of fodder sold within the monthly observations was calculated and then we extrapolated this value to the amount fodder sold in a month by multiplying by the 15 working days per month. We then calculated the monthly value of fodder trading in the area in USD by multiplying the extrapolated amount for one month by price of fodder per tonne.

Hunting/trading of economically important bird species: Hunted bird species were monitored at the main market of Chibayish city for seven months from December to June 2014 (two to seven observation per month). Hunting and trading of bird species in the CM and Chibayish city was found to be an opportunistic, essentially random activity and there were no specific stalls that sold hunted birds in the main market of the city. As a result of the incomplete survey, we did not analyse the data for bird hunting.

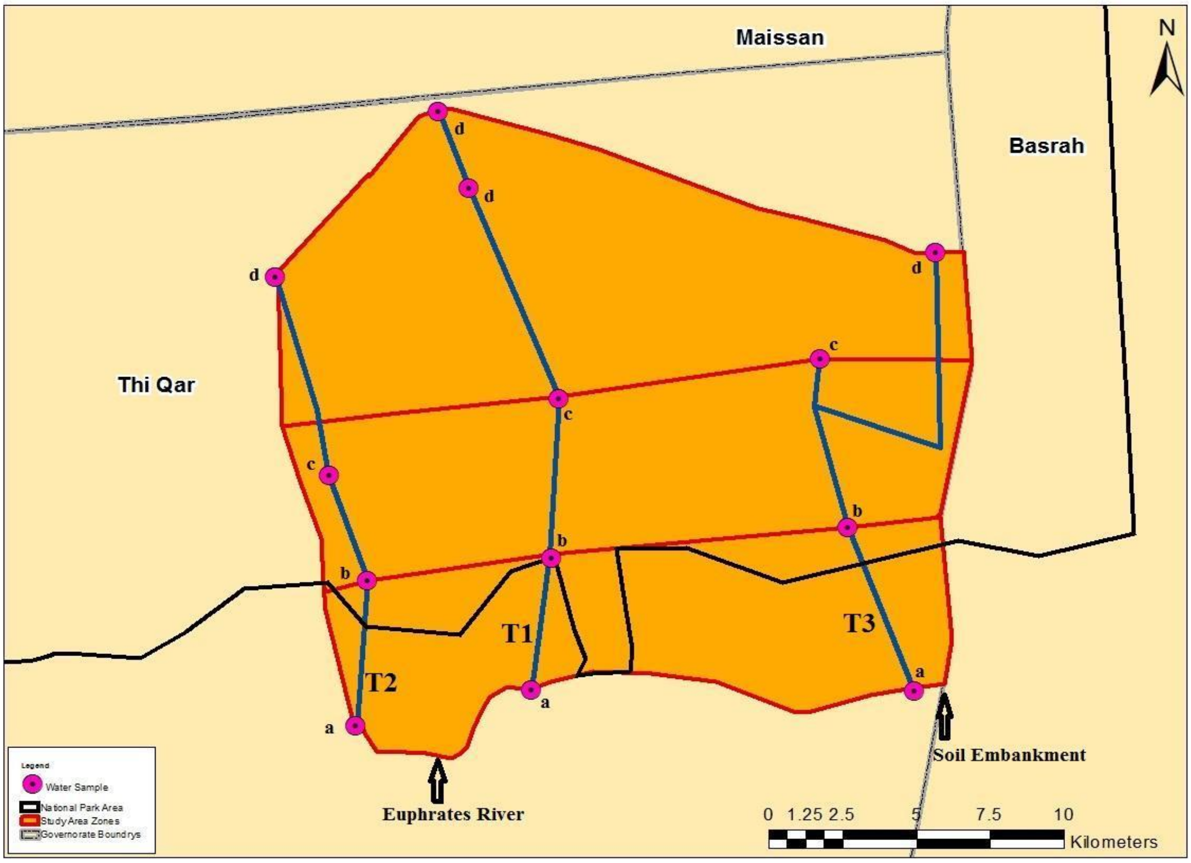

Figure 4. 1. Study area showing the three transects (T1, T2 and T3) and the Euphrates River zone a, and CM zones b, c, and d. Note the zones are demarcated by horizontal red lines.

4.3 Results

4.3.1 *Valuing the CM's ecosystem services*

Two plant species were the most commonly traded in the 40,000 ha study area: *Typha domingensis* and *Phragmites australis*. Plant surveys showed differences between months in the mean amount of plants harvested. April had the highest mean of 34.75 ton ± 0.45 (SE) and January had the lowest mean of 9.17 ton ± 0.23 (SE). The estimated value of harvested plants used for trading during the six-month survey period was 86,637.25 USD in 2014 (Table 4.1). The site with the highest level of harvested plant economic activity in the CM was in transect one.

The majority of economic activity relating to the trading of fish focused around just six species within the study area: *Liza abu* (local name Khishni), *Silurus triostegus (*local name Jirri), *Cyprinus carpio (*local name Samti), *Tiliapia zilli (*local name Bulti or Shanak), *Aspius vorax* (local name Shilik), and *Barbus luteus (carasobarbus)* (local name Himri). *Tiliapia zilli* was the most traded species followed by *Silurus triostegus* and *Liza abu* (Figure 4.2). *Cyprinus carpio* was the most expensive species at 2,000 USD per ton and *Liza abu* was the cheapest species at 400 USD per ton (Table 4.2). Analysis showed there were differences between months in the mean amounts of fish sold from the CM. May and June had the highest means (9.86 tons ± 0.72 (SE) and 9.52 tons ± 1.13 (SE) respectively) and the highest level of economic activity related to fish trading was in transect 1. The total estimated value of trading fish in the CM during the six-month survey period was 551,334.80 USD (Table 4.1).

Socio–economic survey results showed that the water buffalo *Bubalus bubalis* is one of the most important animal species in the CM and trading buffalo milk is an essential local economic activity. The results showed that March has the highest mean amount of milk sold at 4.86 ± 0.03 tons (SE) and May and June had the lowest mean amounts of 1.77 tons ± 0.01 (SE) and 0.98 ton ± 0.01 (SE) respectively (Figure 4.2). The total estimated value of trading water buffalo milk in Chibayish city during the six-month survey period was 167, 303.70 USD (Table 4.1). The results also showed that using fodder as an additional food for water buffalo is an important economic activity in the area. The mean amount of fodder sold varied between months. The largest amount of fodder sold was in January at 2.58 tons ± 2.29 (SE) and the lowest was in June at 0.69 tons ± 0.23 (SE). The estimated value of trading fodder in Chibayish city during the six-month survey period was 54,804.00 USD (Table 4.1).

Bird hunting was recorded as an important economic activity in the CM. Twelve bird species were recorded as traded in the main market of Chibayish city: Common Coot *Fulica atra*, Great Crested Grebe *Podiceps cristatus*, Eurasian Teal *Anas crecca*, Northern Pintail *Anas acuta*, Mallard *Anas platyrhynchos*, Purple Heron *Ardea purpurea*, Northern Shoveler *Spatula clypeata*, Purple Gallinule *Porphyrio porphyrio*, Marbled Teal *Marmaronetta angustirostris*, Grey Heron *Ardea cinerea*, Garganey *Spatula querquedula*, and Black Francolin *Francolinus francolinus* (Table 4.3). The value in USD of these economically important bird species was not included in the total estimated value of the CM's ecosystem services as the opportunistic nature of the hunting and the ad hoc nature of trading made it very difficult to monitor accurately.

In total, the estimated value of the CM's ecosystem services for six months (January – June) in 2014 calculated from monitoring four essential local economic activities was 860,078.23 USD (Table 4.1).

Table 4. 1.Value of the CM's ecosystem services in USD between January and June 2014. Across the entire study period: N = 162 estimates of plants sold, N = 210 estimates of milk sold, N = 84 estimates of fodder sold and N = 126 estimates of fish sold.

Mean amount ± SE (ton) sold / day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Mean over 6 months**	**Value of 6 months in USD**
Harvested plants	9.17 ± 0.23	12.00 ± 0.21	23.60 ± 0.27	34.75 ± 0.45	22.67 ± 0.56	13.33 ± 0.19	19.25 ± 3.91	**$ 86637.24** Mean of 6 months*90 working days*$50/ton
Fish	6.05 ± 0.47	2.81 ± 0.16	0.38 ± 0.04	5.30 ± 0.41	9.86 ± 0.72	9.52 ± 1.13	5.65 ± 1.52	**$551,334.47** Mean of 6 months*90 working days*$1083.33/ton
Water buffalo milk	3.47 ± 0.04	4.20 ± 0.03	4.86 ± 0.03	3.28 ± 0.02	1.77 ± 0.01	0.98 ± 0.01	3.10 ± 0.60	**$ 167, 303.72** Mean of 6 months*90 working days*$600/ton
Fodder	2.58 ± 2.29	1.93 ± 0.31	1.55 ± 0.30	1.13 ± 0.18	1.25 ± 0.21	0.69 ± 0.23	1.52 ± 0.58	**$ 54,802.80** Mean of 6 months*90 working days*$400/ton

Mean amount ± SE (ton) sold / day	Jan	Feb	Mar	Apr	May	Jun	Mean over 6 months	Value of 6 months in USD
								Total = 860,078.23 USD

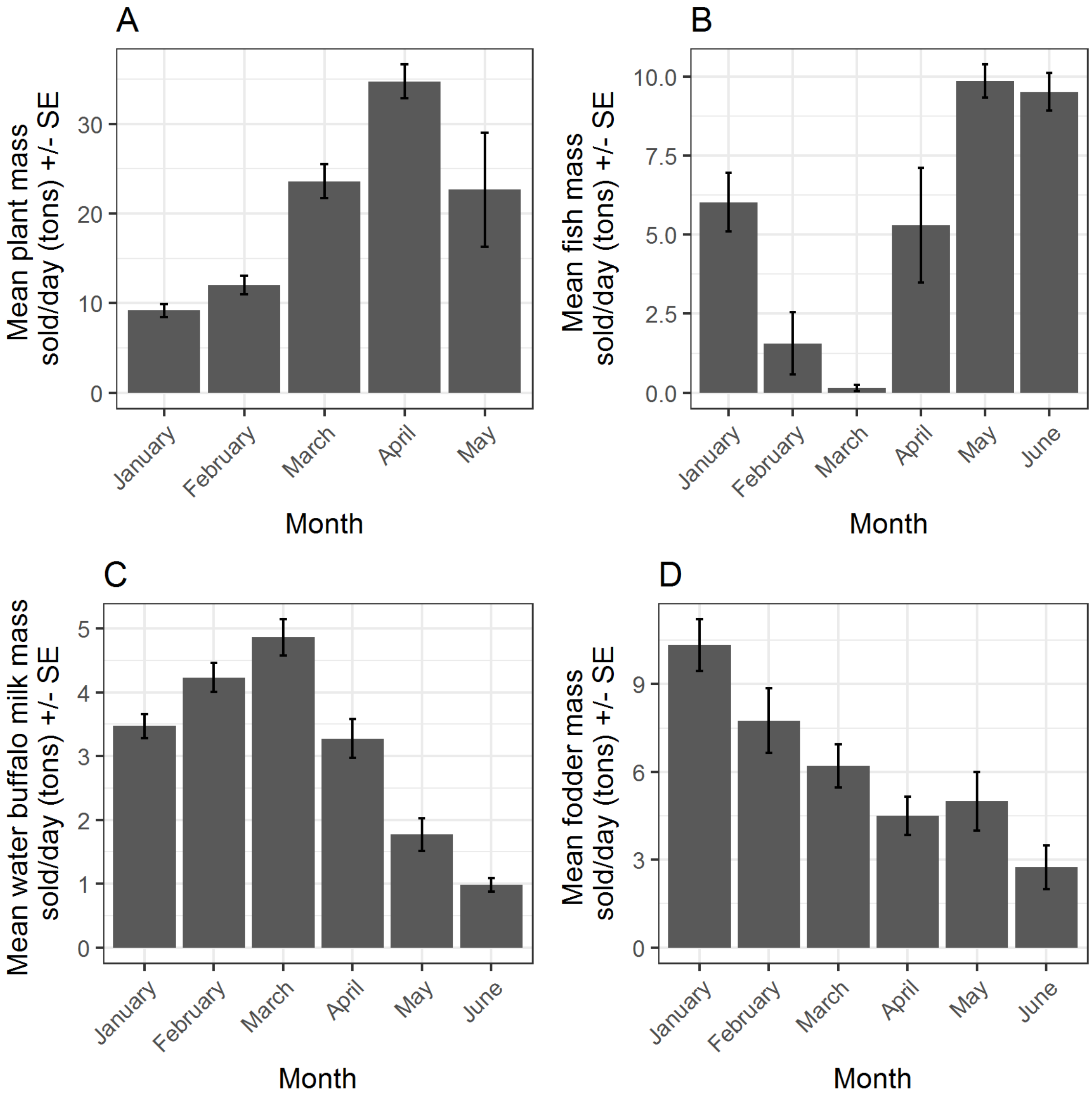

Figure 4. 2.Mean ± 1 SE (between-subjects) amounts traded per day for A) plant mass, B) fish mass, C) water buffalo milk, and D) fodder in the CM from January to June 2014. Across the entire study period: N = 162 estimates of

plants sold, N = 210 estimates of milk sold, N = 84 estimates of fodder sold and N = 126 estimates of fish sold.

Table 4. 2.Fish species price in USD per ton in the CM from January to June 2014 (data were collected during the study survey).

	Liza abu	***Tiliapia zilli***	***Cyprinus carpio***	***Barbus luteus (carasob arbus)***	***Aspius vorax***	***Silurus triostegu s***
$/ton	400	1,250	2,000	1,000	1,000	850

Table 4. 3.Numbers of hunted birds in the CM from December 2013 to June 2014.

Species	**Total hunted**	**Month**
Coot	201	Dec to Mar
Great Crested Grebe	5	Jan
Eurasian Teal	18	Dec and Jan
Pin Teal	40	Dec and Jan
Mallard	64	Dec, Jan, and Feb
Purple Heron	7	Dec, Jan, and Mar
Shoveler	4	Jan
Purple Gallinule	16	Mar and Apr
Marbled Teal	4	Apr
Grey Heron	4	Feb
Garganey	6	Apr

4.4 Discussion

4.4.1 *Valuing the CM's ecosystem services*

We valued the ecosystem services of the surveyed area within the CM (40,000 ha out of the total NP area 141,615 ha) to be 860,078.23 USD during the six month survey period in 2014. This value was calculated by evaluating the focal services provided the CM (trading of fish, water buffalo milk, fodder and harvested plants). The results showed monthly variation in local economic activities and ecosystem services in the area of study. Water buffalo were identified by questionnaires as the most important animals for local people in the CM with 2,500 buffalo recorded in the CM and 17,000 water buffalo heads recorded across the entire CM area and surrounding villages and cities in Thi – Qar province by the Ministry of Agriculture (Chibayish city branch; Figure 4.3 in Appendix 4 provides more information on water buffalo in the marshlands). Water buffalo are very sensitive to changes in water temperature and that controls the residency of local people inside the CM (Shafie, 1993; Abid *et al.*, 2007). Specifically, the buffalo avoid entering the cool water in winter and local people providing fodder directly to the animals in their yards. Thus, the amount of buffalo milk increases in winter and trading milk and fodder becomes the dominant economic activity during winter and spring. Fish trading and fishing activities are fewer in winter and spring than in other seasons as fishing is prohibited in spring. Six fish species were recorded as the most dominant species used for trading and food, which is interesting as 28 freshwater fish species were described in Iraq from 1843 – 2011 (Jawad, 2012). The *Tilapia zilli* fish species was introduced to the CM 2010 and is considered as an invasive (Nature Iraq, 2017) and our results indicate it is the most traded fish species in the site. The other non-native fish species, *Silurus triostegus* is not consumed by local people due to religious reasons, hence, it is used mainly in trading. *Cyprinus Carpio* is the most palatable fish species for the local people, but it is expensive. Thus, *Liza abo*, which is the cheapest fish species is consumed largely by the local population. Changing the historical hydrology of the CM and the introduction of invasive species has negatively impacted the native fish species *Barbus Sharpeyi* and *Barbus xanthopterus* (Hussain *et al.*, 2009) and probably contributed to their disappearance from the study area. Although the two non-native fish species *Tilapia zilli* and *Silurus triostegus* have negatively affected the ecology of native fish species, they provide economic support for the local people inside the CM (Rubec, Alwash and Bachmann, 2009). Economic activity relating to harvested plants is important to the CM's local people, who use plants for building houses, hand crafts, water buffalo fodder, and as a main source of income. We showed that spring is the peak of plant trading activity in the CM. Moreover, transect one is the most used for plant harvesting.

Despite the current challenges that face the CM owing to issues of water scarcity, the site continues to provide valuable services to the local people. There are clear monthly differences in trading at the area of study, with local people relying most on milk trading in winter, milk and plant trading in spring and fish trading activity in summer and autumn.

Using a modified version of the TESSA toolkit has provided greater understanding of the ecosystem services provided by the CM and has highlighted the crucial role of nature in supporting sustainable well-being for humans living in close proximity to the CM. In addition, the results can be used to enhance local policy and aid management plans of the NP. We currently have no data on how our estimated value for the CM's ecosystem services relates to the value of other economic activities in the area. However, we must caution that our estimated value of the ecosystem services provided by the CM most likely underestimates the true value of the services provided given that we carried out surveys for only a part of the year. This is also in part because we could not include some potentially important economic activities in our valuation. The focal activities that were not included are:

i) Trading of economically important birds. Although we monitored the main market at Chibayish City during our survey, we did not add the economic value to our overall estimation because we think giving a precise value for the trading of birds requires further intensive and targeted surveys.

ii) Using plants for house construction, hand crafts and as fodder for water buffalo.

iii) Eco-tourism, which has increased dramatically in the CM (thousands of tourists from inside and outside Iraq now visit the area during winter and spring especially, in the last two years (Ministry of Environment, personal communication 2017). This activity could support and enhance local income; however, uncontrolled tourism could have negative impacts on the CM's ecosystem and wildlife.

iv) Using motorboats for transportation inside the CM as an additional source of local income.

Ultimately, although the CM site is facing challenges from changes to the hydrology of the Euphrates River, uncontrolled use of ecosystem services, changes in water quality and the disappearance of some important native fish species, the site still supports much biodiversity, as well as providing the local people with valuable ecosystem services. Iraq currently faces significant decreases in its cropland area, (which includes marshlands) by approximately 30,000 ha/year (Gibson, Campbell and Zipper, 2015). Thus, to support, protect, and improve ecosystem services provided by the CM, the local authorities and government should account for the extrinsic and intrinsic value of the natural services from the CM and take serious steps to enhance water quantity and quality inside the CM. Moreover, the value of the ecosystem services provided should be added and embedded within the national budget. Finally, we recommend carrying out long-term surveys by repeating our methodology for at least one year and expanding the study area to include all NP areas, which could provide a more accurate estimation of the ecosystem services provided by the CM. Iraq has 220 Key Biodiversity Areas and repeating our methodology to value ecosystem services inside all KBAs could provide a clear image of nature's value to the Iraqi economy.

4.5 Appendix 4

Table 4. 4.Appendix: PRA questionnaire question and answers. The answers were collected from people working in Chibayish city authority, people working in NGOs and people working in the focal economic activities. Sample size was 30.

PRA Questions	Answers
1. What are the most important activities for the CM's local people and source of income?	- Water buffalo grazing - Selling milk of water buffalo - Plant harvesting from the CM and selling the plants. - Fishing in the CM - Feeding water buffalo by using plants of the CM and fodder.
2. What are the most important natural resources in the area?	Local people in the CM are highly dependent on two main natural resources: the Euphrates River and ecosystem services that are provided by the CM.
3. What are the difference between historical and current activities for local people?	CM "Ma'adan" Arabs still use the resources of the wetland like their Sumerian predecessors.
4. Is there any trade for the natural resources? What are the methods for trading?	Local people sell their goods "that are collected from the CM" daily to other provinces. There are daily economic trading activities on the main street of Chibayish city. There are no strict controls and rules from the government, the local authority and farmers' associations (fishing is prohibited for 2 months/year during the fish breeding season; although, this rule can help to control fishing, the rule is flexible and there is no enforcement) therefore, the trade is highly dependent on the local people's' situation, relationship, and daily income.
5. What are the most important trade/economic locations or assembly points in the area?	Although, the local people's activities are effectively random, there are four main economic assembly points that can be monitored and provide a clear representation of the local people's activities.

6. What are the most important domestic animals in the area?	“Ma’adan” Arabs are not farmers (they buy their daily agricultural products from the market, which come from other provinces) and they are highly dependent on natural ecosystem services. Historically, there is a strong relationship between the Ma’adan and water buffalo, which is considered the most important and main domestic animal (considered one of the important landmarks in the area). 17,000 water buffalo heads were counted in Chibayish city and area of the CM (report of agriculture ministry, 2014). The Ma’adan’s settlements, movements inside the marsh, migration, daily income and daily food, are highly dependent on water buffalos.
7. Which governmental ministries are involved in the marshlands’ management?	There was increasing interest by the government and non-governmental institutions started after 2003 in the marshlands of southern Iraq. There is clear input for the marshlands’ management plans by the Iraqi ministry of Environment, ministry of Water Resources, ministry of municipalities, ministry of Agriculture and local authorities.

8.	What are the most important programs/projects started after 2003?	There are many small projects that were completed in the area. However, there are two main productive programs/projects that reflected positively on the area and supported local management plans: 1) New Eden (NE) master plan that was funded by the Italian government and implemented by Nature Iraq (National NGO) in cooperation with ministry of Environment, water resources, and municipalities, and local authority. There are several landmark projects that were conducted by the NE program such as: the construction of nine gates to control the water of the Euphrates River that goes to the CM, announcing the CM as 1st national park in the country, and conducting a KBA survey for 220 natural sites in Iraq including the CM. 2) Chibayish City urban plan. This project helped to control projects on the border and buffer zones of the national park. 3) Canadian-Iraq Marshlands Initiative (CIMI) that was funded by the Canadian International Development Agency (CIDA). This initiative focused mainly on supporting academic work and publications on the marshlands with cooperation with some Iraqi universities. 4) Strategy for Water and Land Resources in Iraq (SWLRI). This project focused all over Iraq including the CM.

Table 4. 5.Appendix: List of survey dates in the CM from October, 2013 to June, 2014.

Month	Oct, 2013	Nov, 2013	Dec, 2013	Jan, 2014	Feb, 2014	Mar, 2014	Apr, 2014	May, 2014	Jun, 2014
Day of the survey	28	9	16	17	17	19	16	17	9
	29	10	17	19	18	20	17	18	10
		11	18	20	19	21	18	19	11

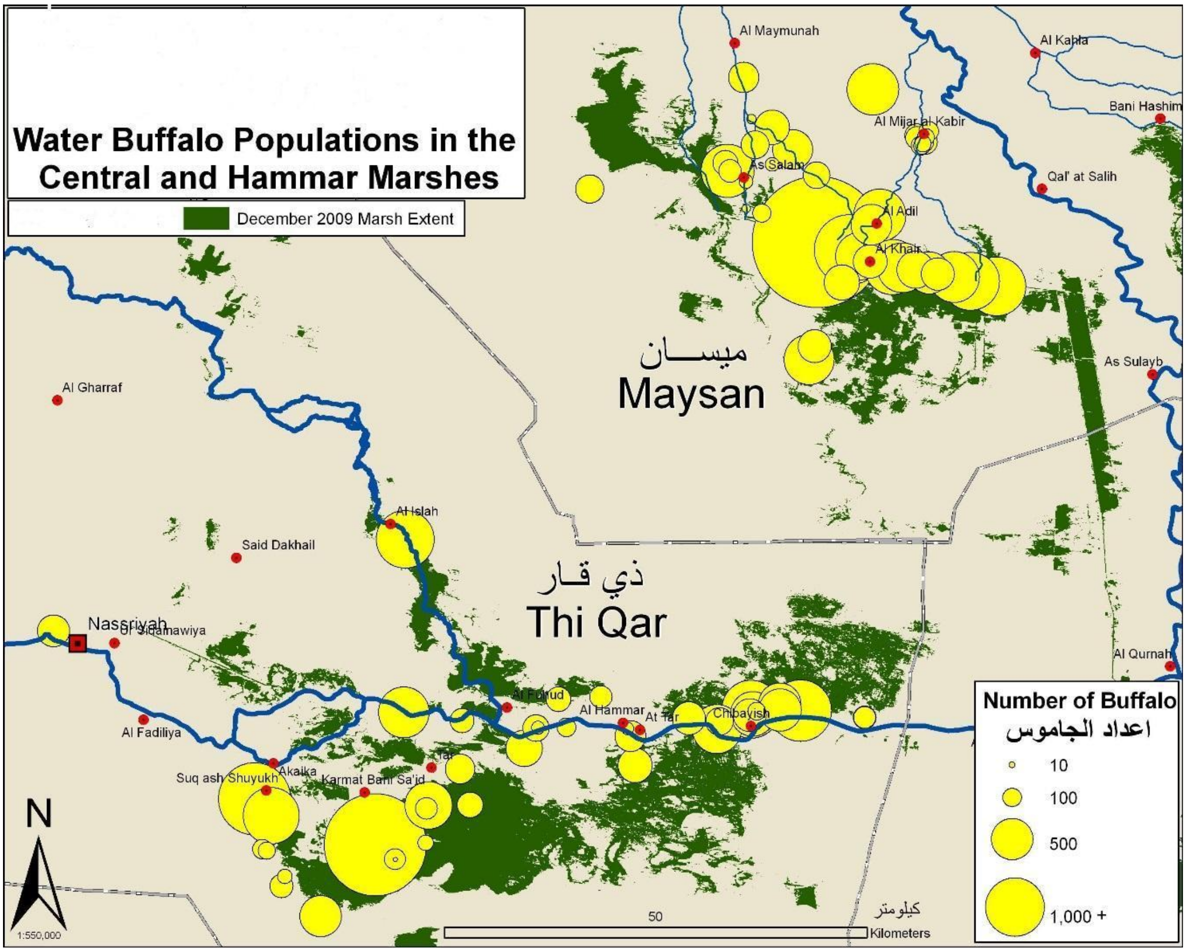

Figure 4. 3.Water buffalo population in the Central and Hammar Marshes 2009 (Holmes, 2010).

Chapter 5. Water quality of the Central Marsh in Southern Iraq

5.1 Introduction

Iraq's Central Marsh (CM) is one of the important wetland/ecosystems in the south of Iraq (Al-Ansari, Knutsson and Ali, 2012). The CM site provides a many ecosystem services to the local population, which has undergone a rapid increase from 41,000 in 2005 to 152,844 in 2015 (Central Statistical Organisation Iraq, 2017). The site was historically provided with water from the Tigress and Euphrates rivers, which are the main two rivers in the Mesopotamian basin. The CM was desiccated by the government in the 1990s and re-flooded in 2003 (Richardson and Hussain, 2006). As a consequence of the restoration, the hydrology of the CM was changed so that ever since it has totally depended on inflow from the Euphrates River alone (Nature Iraq, 2006b). Naturally, the Euphrates River collects 88% and 12% of its water from Turkey and Syria respectively in the upstream region, with no natural input to the Euphrates from Iraq (Al-Ansari and Knutsson, 2011). The natural flow inside Iraq reached 60 billion cubic meters in 1963 before the constructions of dams in upstream countries, while it decreased significantly after dam construction and especially after implementation of the GAP project in Turkey that started in 1990 (Nature Iraq, 2006b). The Euphrates' water in the upstream provinces inside Iraq is used for agriculture irrigation and municipal water supply, with sewage water dumped directly into the river in some upstream provinces. The Euphrates played an essential role in diluting pollution that came from agriculture and irrigation and other human activities in the upstream provinces before 1990. The huge volumes of the water in the Euphrates at that time (which helped to flood 3000 km^2 of the CM) and the low human populations both in upstream provinces and within the CM itself allowed the Euphrates to dilute pollution in this way as concentrations of pollutants were still relatively low and the high volumes of water effectively swept pollutants away. Following the significant decrease in water volume flowing through the Euphrates with a combined significant increase in human population and thus municipal discharge of sewage, the capacity of the Euphrates to dilute pollutants was severely impaired.

Despite the considerable efforts that were spent by the Iraqi government and various civil societies post-2004, it was not possible to restore the CM to 100% of its original pre-desiccation area as a direct consequence of the water scarcity in the Euphrates. As a result, the local authority in Chibayish City, the Ministry of Water Resources, the Ministry of Environment and other stakeholders decided to implement several actions to help to reduce impact of water scarcity in the Euphrates on the restoration of the CM. The actions were: 1) to declare 141, 615 ha of the CM as a national park in 2013 (Alwash *et al.*, 2009; Pearce, 2013); 2) to construct 9 gates with the capacity to control 1.7m of water between the Euphrates and the national park in 2006; and 3) to construct a soil embankment in the Euphrates in 2011 between Chibayish city in Thi Qar province and Modina city in Basra province. Thus, all of these actions have had the effect of only allowing the Euphrates' water to pass through the CM and past the embankment when the water level reaches 1.7m in the river, which is unlikely to occur given the water scarcity in the Euphrates.

The Euphrates River meets the Tigress River after Chibayish city in Basra province. The soil embankment that cuts across the Euphrates River could prevent it from ever meeting the Tigress River and effectively has made the CM the terminal site for all Euphrates water and its associated high concentrations of different pollutants. The impact of establishing the soil embankment on the CM's local people and ecosystem services has not been examined by the Iraqi government or scientists. Previous studies have noted that there are significantly raised salinity levels within the CM (Al-Maarofi, Douabul and Al-Saad, 2012) but there has not been consensus on the cause of this change. Due to a lack of information about the impact of the soil embankment and water scarcity on the CM, this chapter aims to provide baseline data on water quality within the CM and to compare the results with water quality in other Mesopotamian marshlands. This will allow us to evaluate the current role of the CM in cleaning water from the

Euphrates River. There are currently no published studies that have examined the water quality within the CM with the aim of assessing the impact of the embankment (Al-Ansari, Knutsson and Ali, 2012). Such a study could help both policy makers and local people have a better understanding of the impact of water scarcity in the Euphrates River and its consequences on both people and wildlife in the CM.

The overall aim of the chapter was to compare water quality at varying distances from the Euphrates River as it flowed into the CM. I predicted that as the further water flowed into the marsh the more the water quality would improve if the CM was acting to clean the water.

5.2. Methods

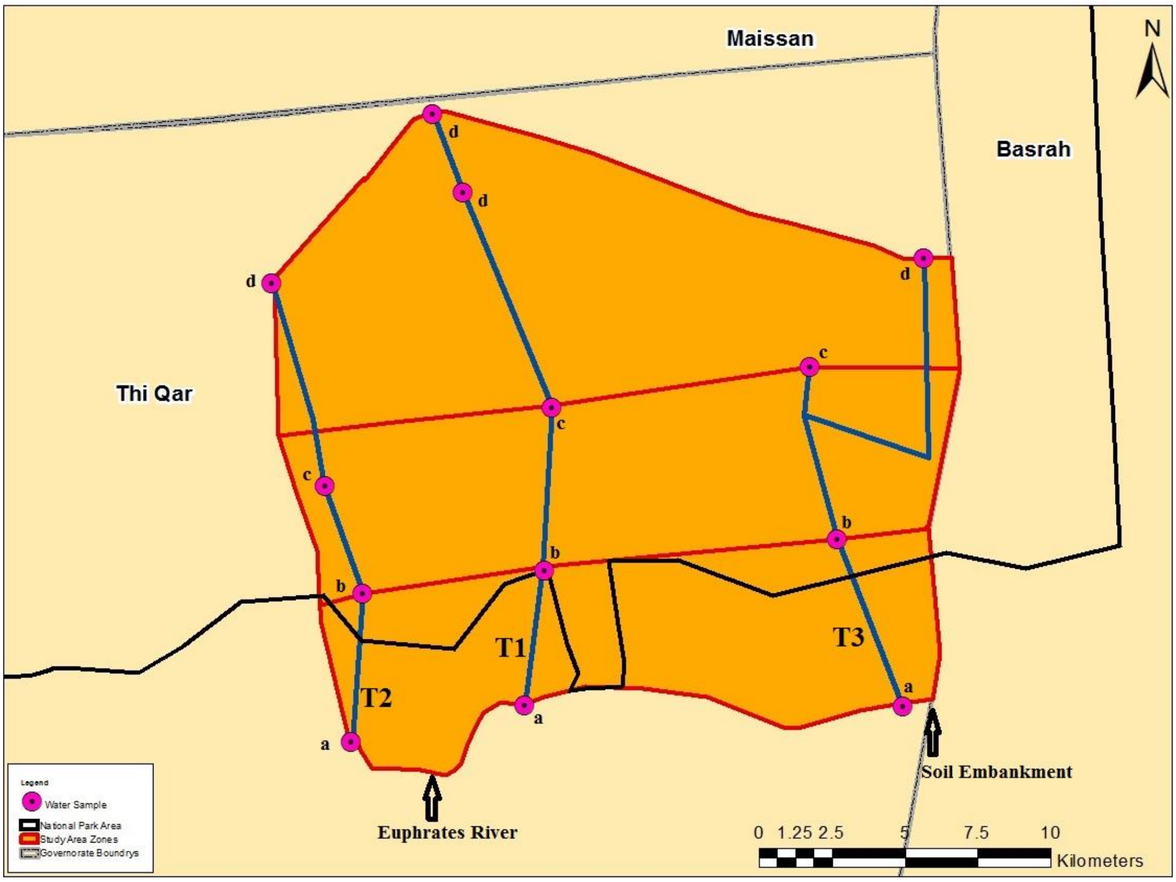

Figure 5.1. Study area showing water sampling sites (shown as pink dots) and transects 1, 2, and 3, and Euphrates River zone a and CM's zone b, c, and d.

Field Survey: sampling protocol

Eight surveys were carried out in the CM once a month from November 2013 - June 2014 at the same time as the bird and turtle surveys were undertaken (see Chapters 2 and 3 for further methodological details). Water samples were first collected from Zone A (the Euphrates River) in the south in the morning and were sequentially collected along transects in zones B, C, and D (Figure 5.1). Water sampling sites are shown in Figure 5.1; five sites were chosen in transect one, and four sites were chosen in transects two and three. All field samples were taken by Nadheer Fazaa and data on monthly water levels for the Euphrates River were supplied by the Iraqi Ministry of Water Resources (Chibayish branch). Hanna portable instruments (HI 9811-5) were used to measure pH/EC/TDS/˚C of water directly in the field. Two kinds of bottle samples (glass and plastics) were used to sample one litre of water/site.

Laboratory analysis

Water samples were analysed in the water laboratory of the Environmental Centre in the University of Technology in Baghdad by using the standard methods recommended by the American Public Health Association (American Public Health Association, 1999). Samples were sent from the CM to the laboratory in Baghdad within an ice box. Eighteen parameters were analysed in the lab to measures concentrations of water salinity, nutrients, anions, and heavy metals between the Euphrates River and the Central Marsh. The parameters were: Electrical Conductivity (EC), salinity, Total Dissolved Solid (TDS), Total Suspended Solids (TSS), Total Hardness, NO_2, NO_3, PO_4, Na, K, Cl, Ca, Mg, Cu, Ni, Pb, Cd, and Zn. These parameters were chosen because they encompassed a range of physical and chemical indicators of water quality and as such provide a useful baseline for future studies. For example, heavy metals such as Zn can have negative impacts on both humans and wildlife throughout the food web and so it is important to know if concentrations have increased since the embankment of the Euphrates.

Statistical analyses

ANOVAs were performed to test the influence of zone, transect, and month of sampling, and their interactions with the physical and chemical water parameters. Model residual plots were examined to check for assumptions of normality and homogeneity of variance. All models satisfied these assumptions. All of the analyses were conducted using R.

5.3. Results

A. ***Field survey:***

Results from the field surveys for pH (Figure 5.2), EC (Figure 5.3) and TDS (Figure 5.4) indicated differences between the Euphrates River zone and marsh zones. pH in the River zone was higher than pH in the marsh. December had the highest value of pH and June had the lowest, and transect two had the highest values of pH compared with transect one and three. The lowest values of EC and TDS were recorded in the river zone during January and in transect one (Figure 5.2).

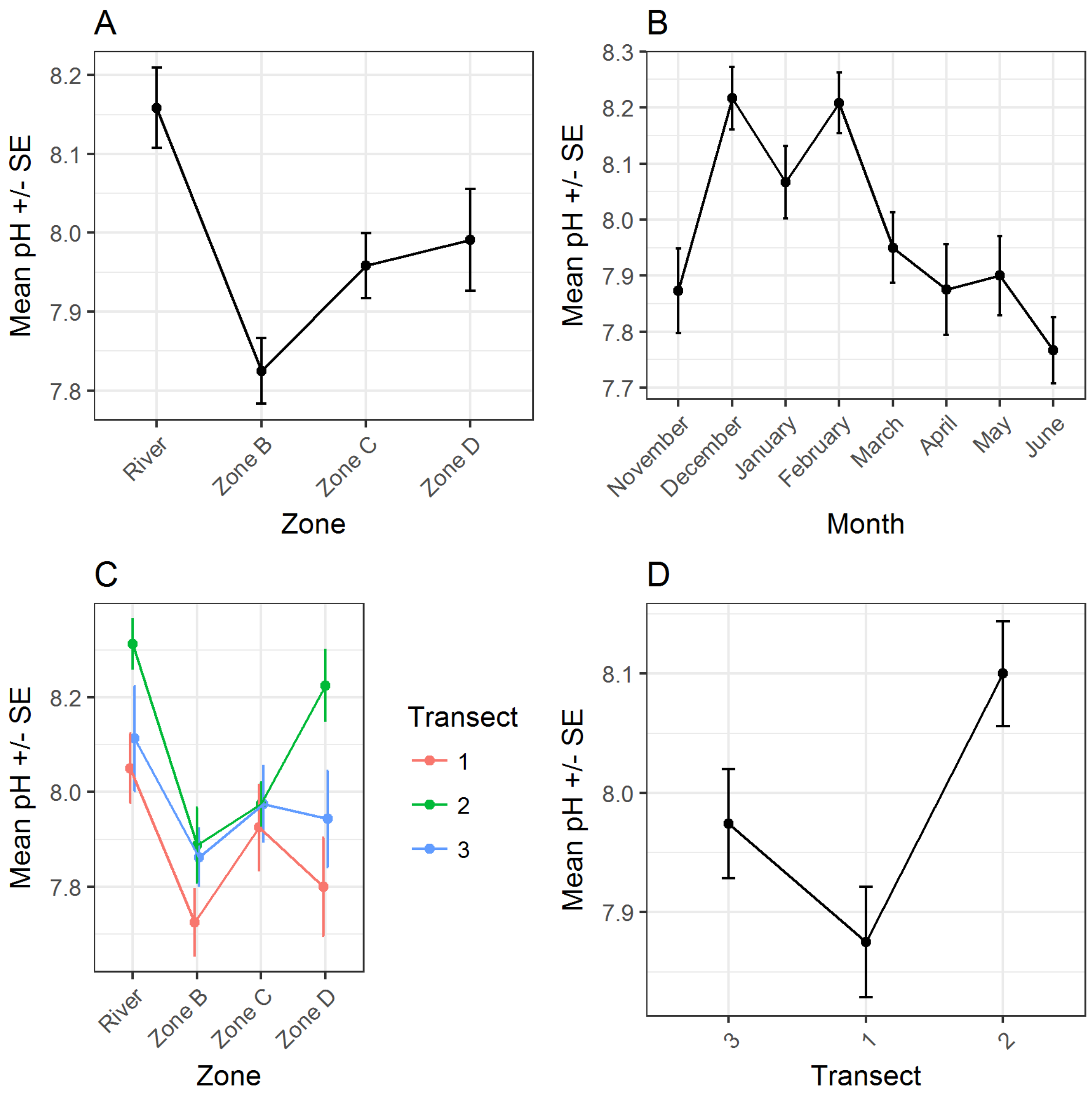

Figure 5.2. Field measurements of mean ± SE (between-subjects) pH in the CM for A) zones; B) months; C) zone and transects; and D) transects from November 2013 to June 2014. N = 96 samples across entire field seasons.

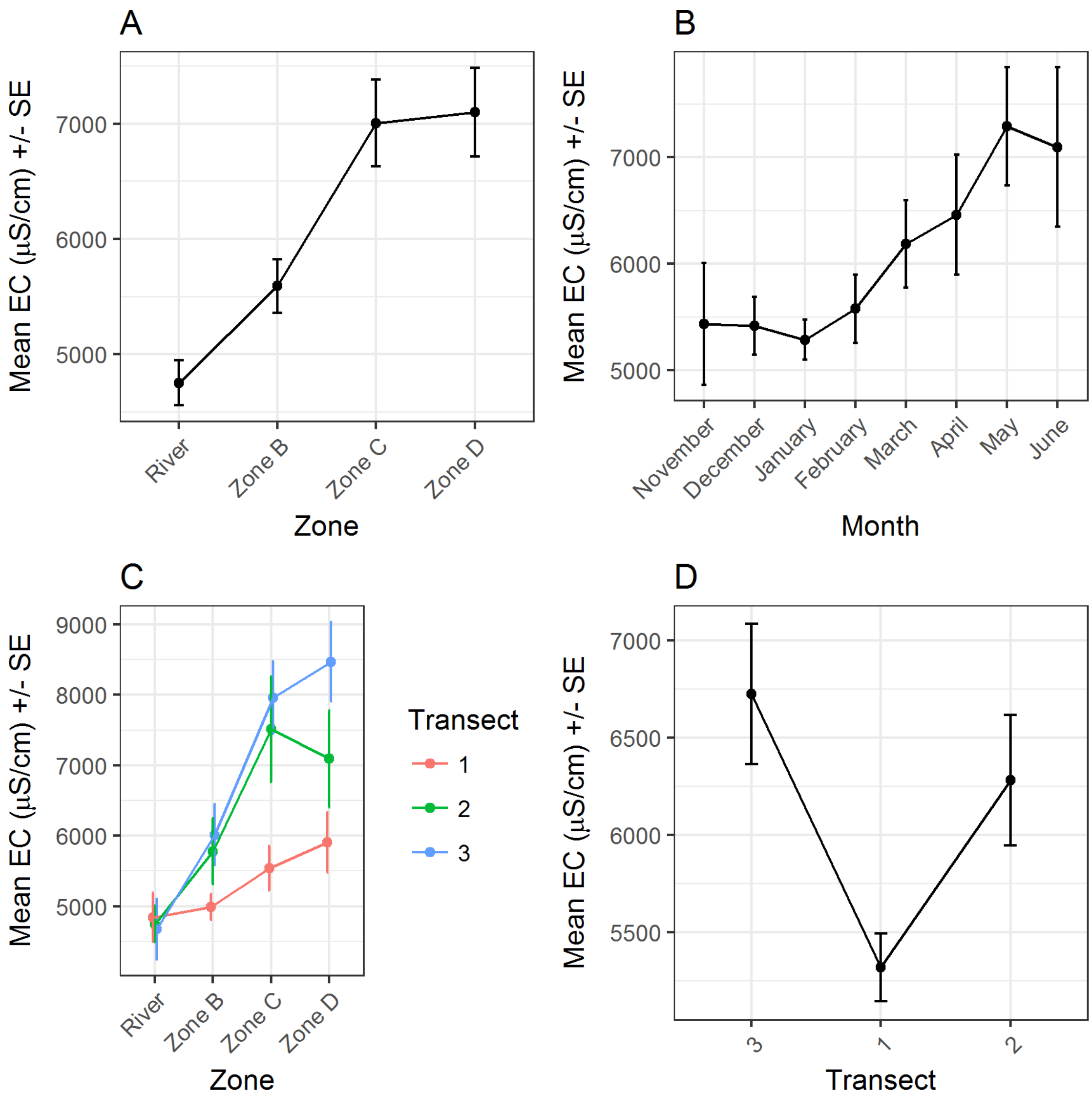

Figure 5.3. Field measurements of mean ± SE (between-subjects) Electrical Conductivity value (EC) in µS/cm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June, 2014. N = 96 samples across entire field season.

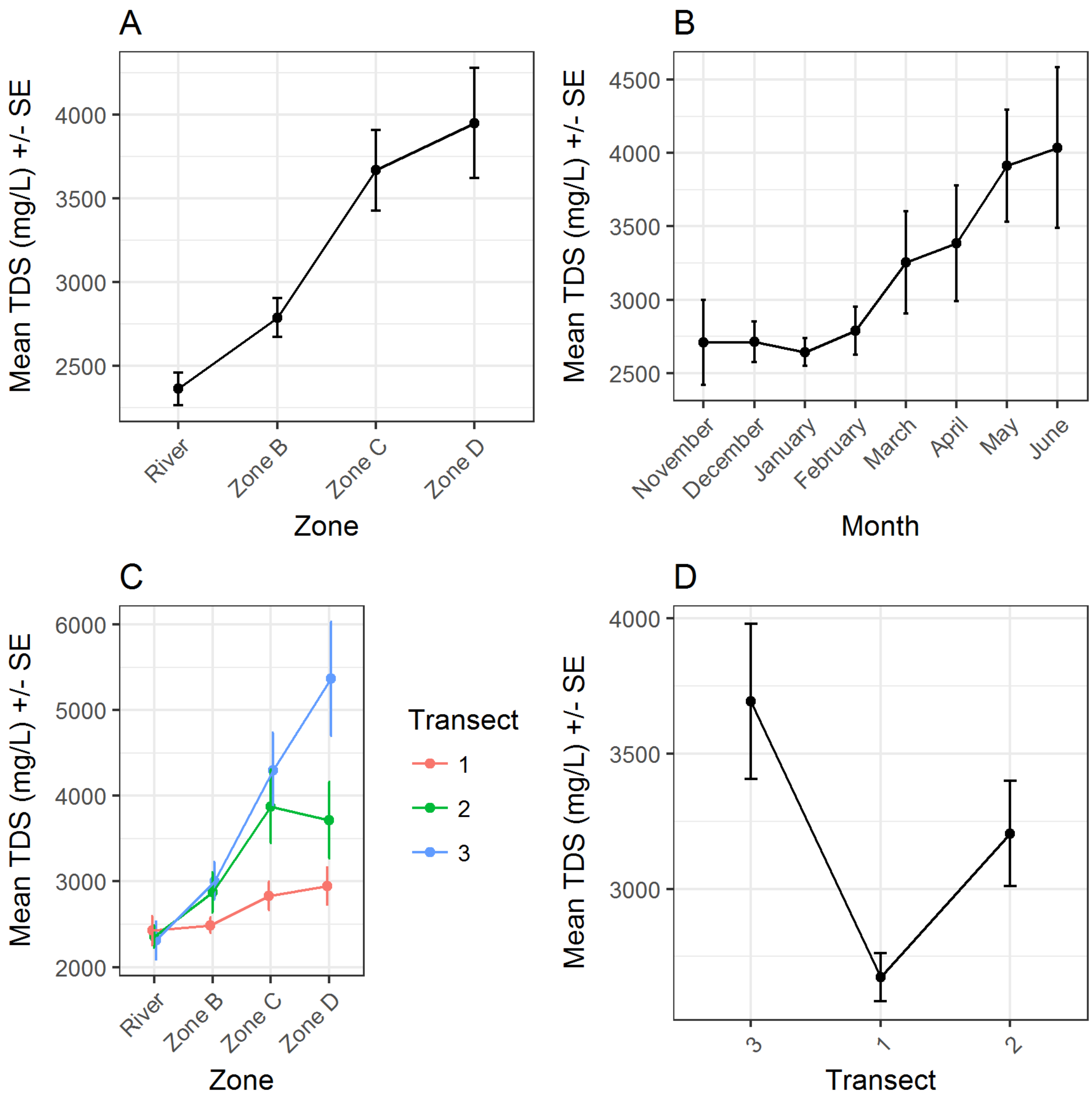

Figure 5.4. Field measurements of mean ± SE (between-subjects) Total Dissolved Solids (TDS) values in mg/L in the CM for A) zones; B) transects; C) zones and transects; and D) transects from November 2013 to June, 2014). N = 96 samples.

B- *Laboratory Analysis:*

Results of the laboratory analysis for 18 parameters (EC, salinity, TSS, TDS, turbidity, NO_2, NO_3, PO_4, Na, K, Ca, Mg, Cl, Cu, Ni, Pb, Cd, and Zn) indicated variation between river and marsh zones. We divided the results into 4 groups as follows: group 1 (EC, salinity, TSS, TDS, and turbidity) to evaluate water quality and give an overall assessment of salinity and turbidity in the Euphrates River and the CM; group 2 (NO_2, NO_3, and PO_4) to evaluate nutrients in the river and the CM; group 3 (Na, K, Ca, Mg, and Cl) to evaluate ions in the water; and group 4 (Cu, Ni, Pb, CD, and Zn) to evaluate heavy metals in the water.

Group 1: The results indicated that all river values of EC (Figure 5.5), salinity (Figure 5.6), TSS (Figure 5.7), TDS (Figure 5.8), and turbidity (Figure 5.9) were less than values within the CM. Inside the CM the EC and salinity values were higher in zone D, while the TDS and turbidity values were higher in zone C. All values of group one were higher in transect 3 compared with transect 1 and 2.

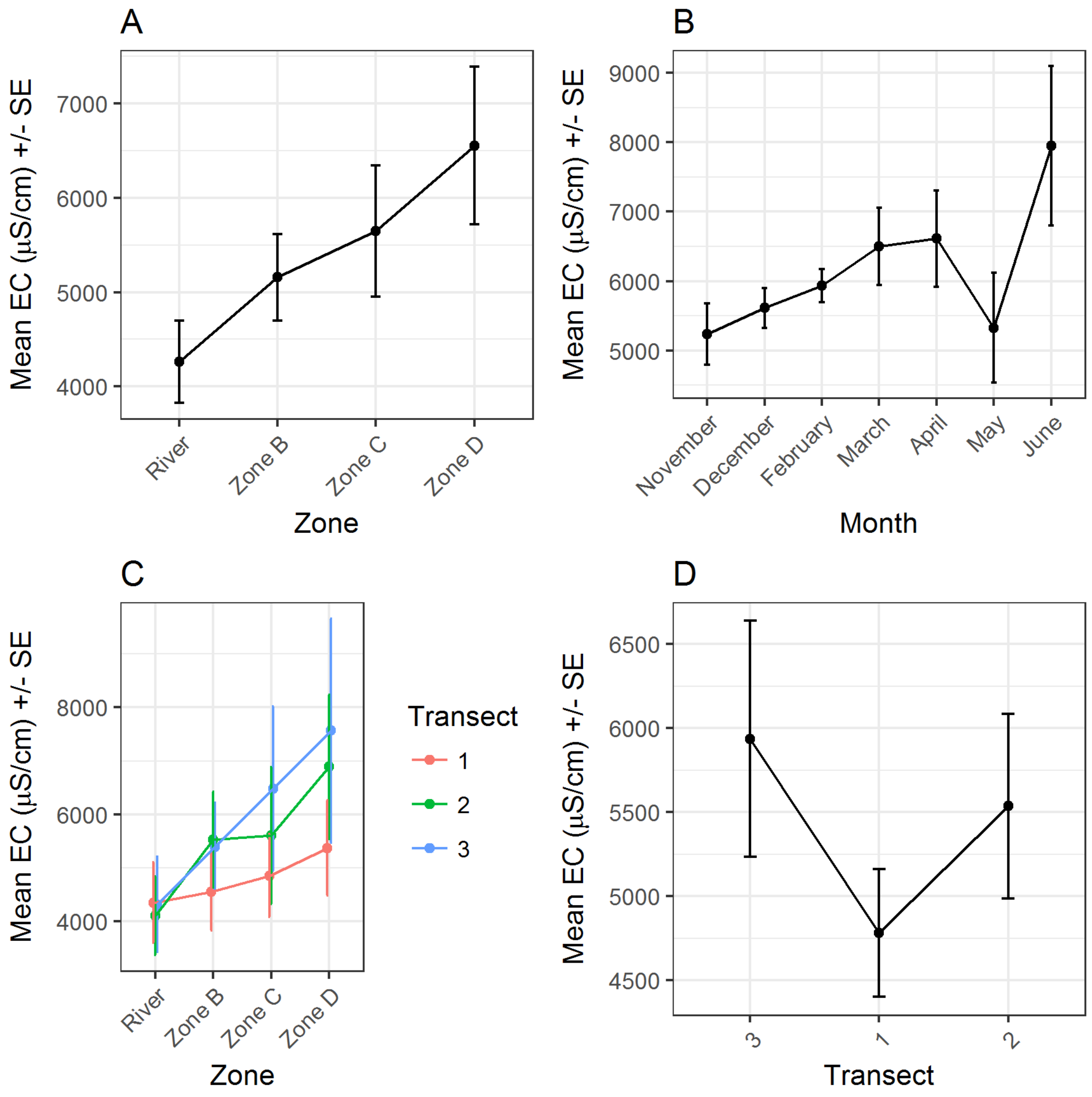

Figure 5.5. Laboratory mean ± SE (between-subjects) EC values in the CM in µS/cm for A) zones; B) months; c) zones and transects and; D) transects (from November 2013 to June 2014. N = 96 samples across entire study period.) A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=3.70, p<0.001) and zone and month ($F_{21,49}$=3.70, p<0.001) but not transect and zone ($F_{3,49}$=1.80, p=0.20).

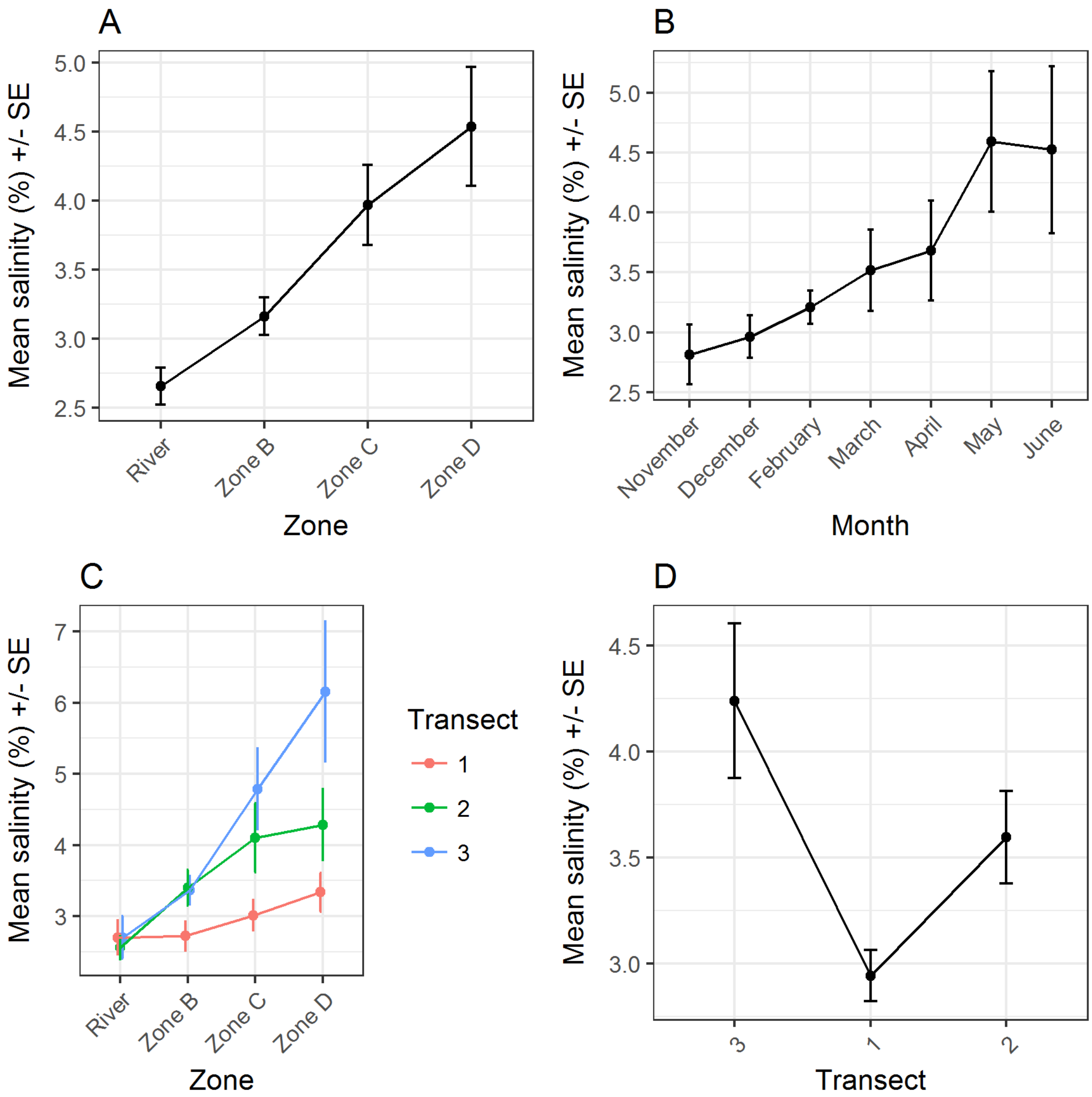

Figure 5.6. Laboratory mean ± SE (between-subjects) of water salinity values in % in the CM for A) zones; B) months; C) zones and transects; and D) transects from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction

between transect and month ($F_{7,49}$=3.90, p<0.001) and zone and month ($F_{21,49}$=6.10, p<0.001) and transect and zone ($F_{3,49}$=16.50, p<0.001).

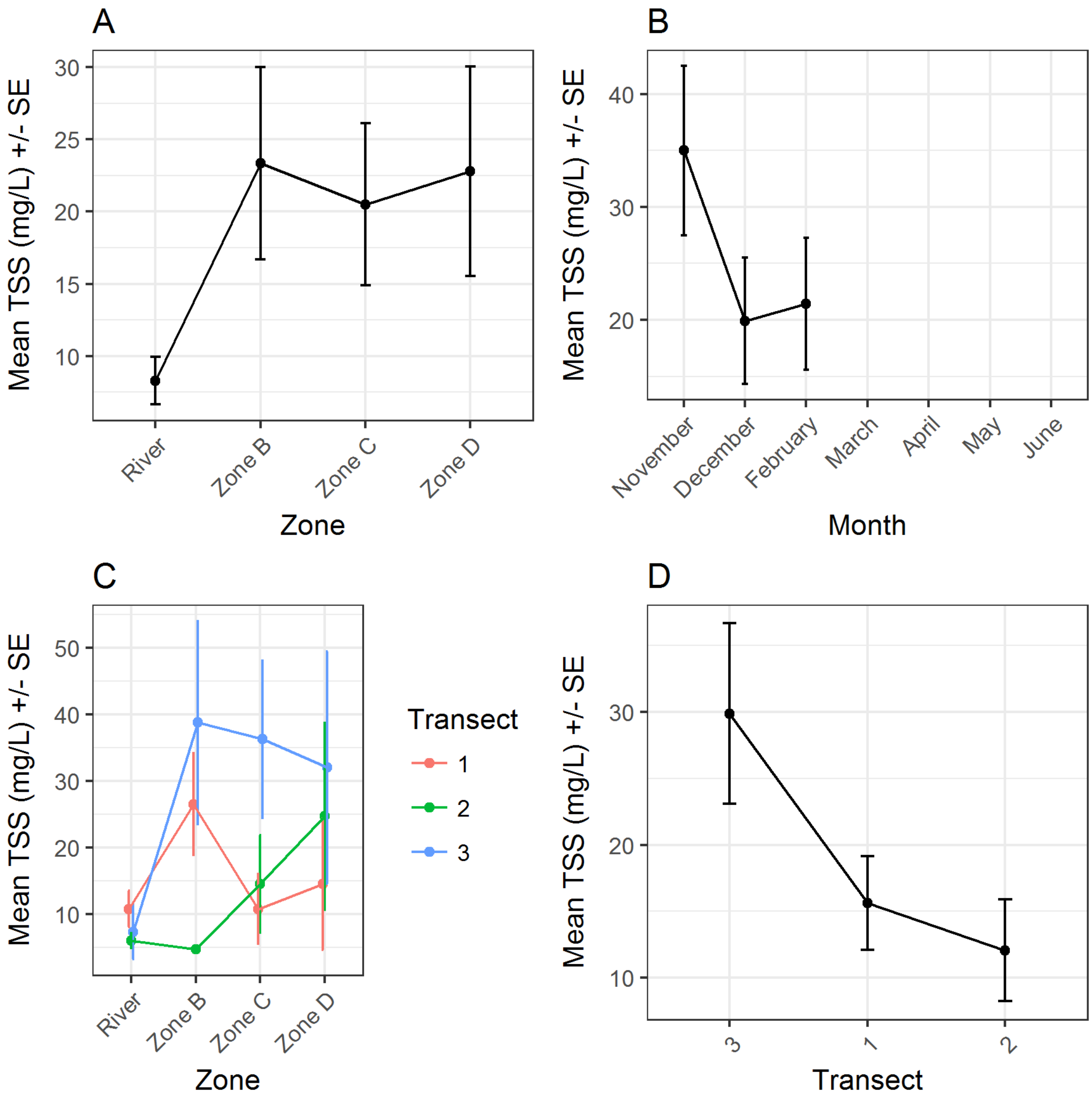

Figure 5.7. Laboratory mean ± SE (between-subjects) TSS values in mg/L in the CM for A) zones; B) months; C) zones and transects; D) transects from November 2013 to February 2014. N = 44 samples across entire study period. A two-way ANOVA showed that there was no statistically significant interaction between transect and month ($F_{3,21}$=1.60, p=0.20) and zone and month ($F_{9,21}$=0.50, p=0.90) and transect and zone ($F_{3,21}$=0.80, p=0.50).

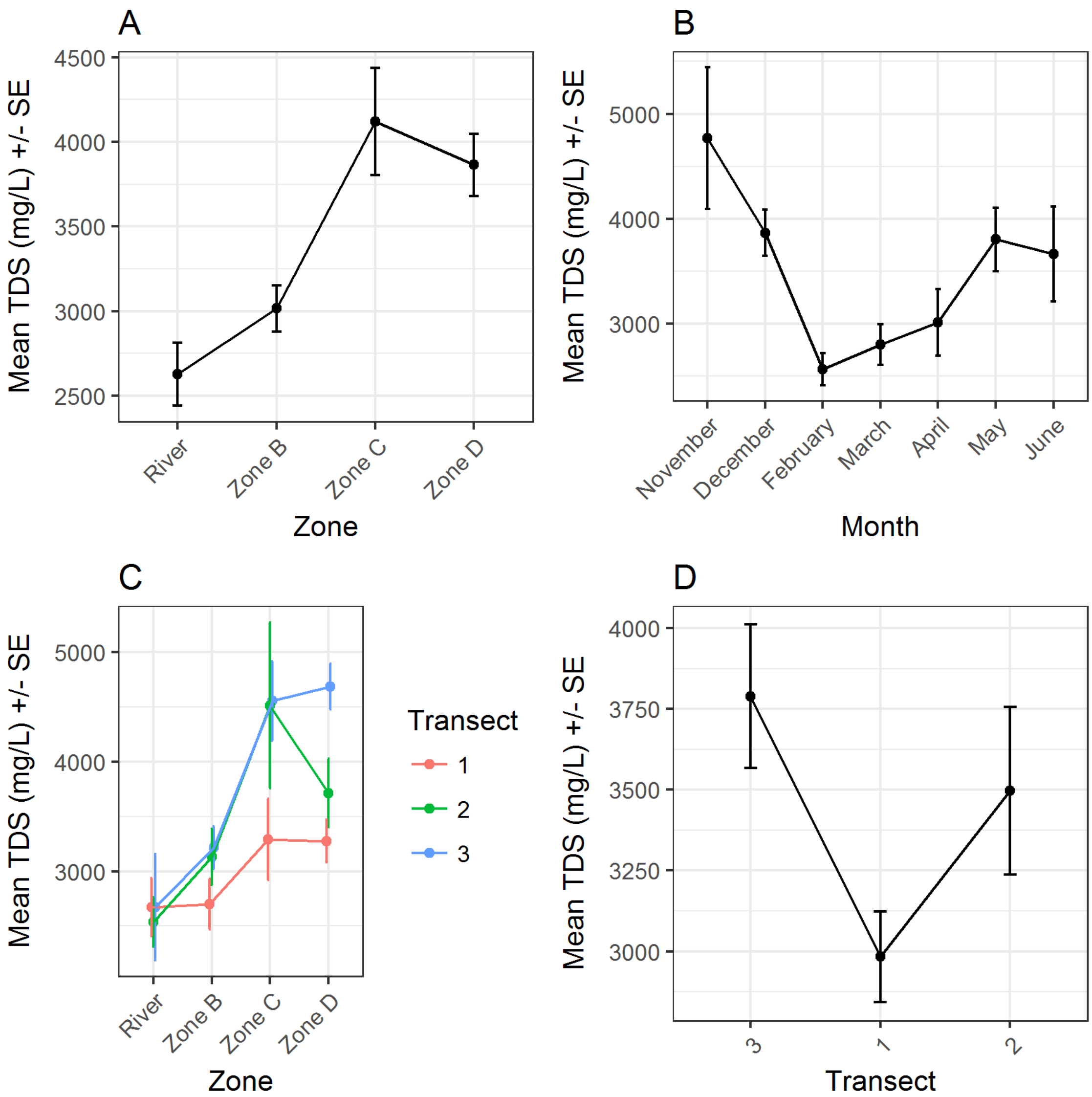

Figure 5.8. Laboratory mean ± SE (between-subjects) TDS values in mg/L in the CM for A) zone; B) month; C) zones and transects; and D) from November 2013 to June, 2014). N = 96 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{7,49}$=3.70, p=0.80) but there was between zone and month ($F_{21,49}$=3.70, p<0.001) and not transect and zone ($F_{3,49}$=4.50, p<0.001)

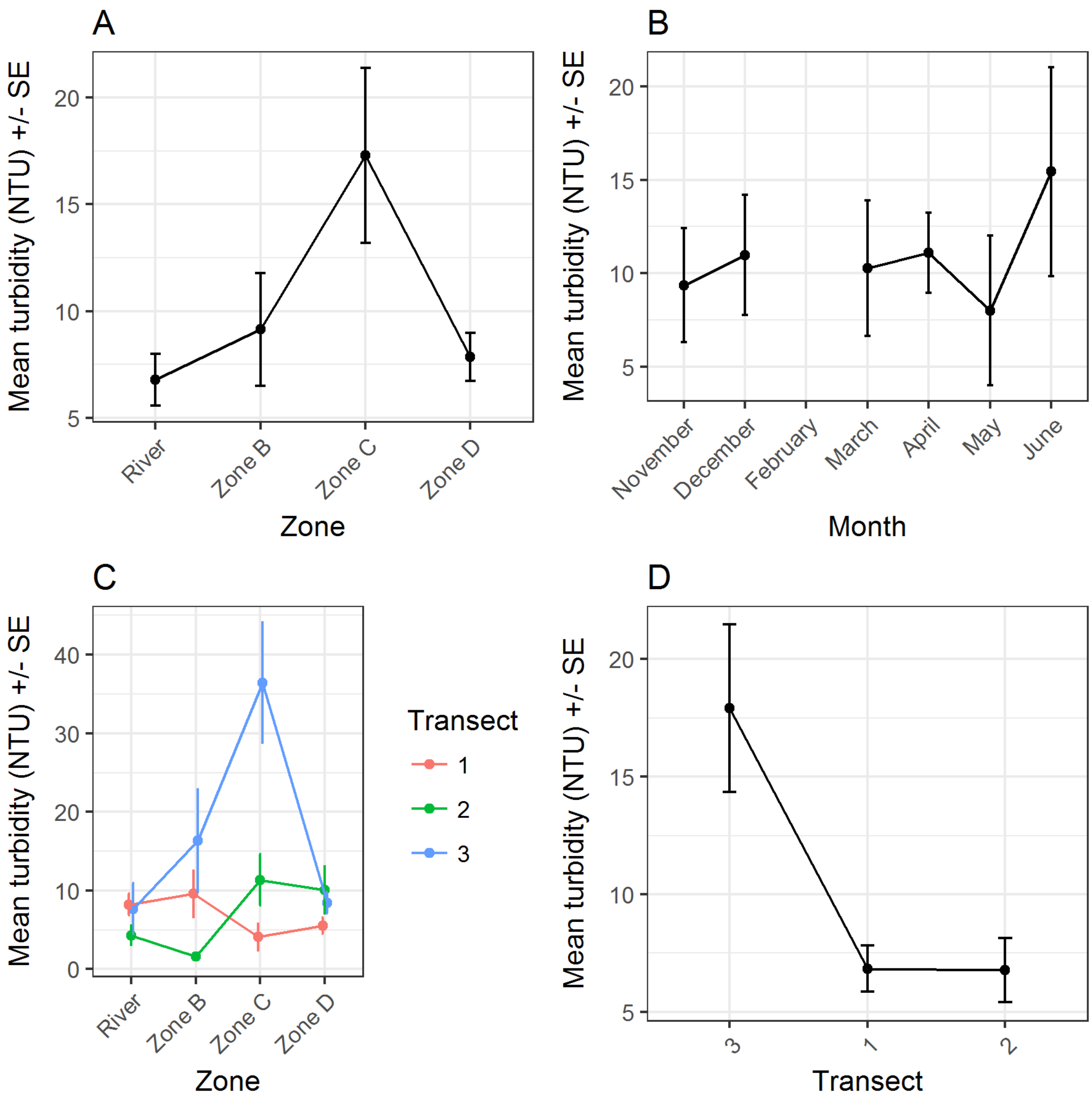

Figure 5.9. Laboratory mean ± 1 SE (between-subjects) turbidity in NTU in the CM for A) zones; B) months; C) zones and transects; and D) transects from November 2013 to June, 2014). N = 80 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{6,42}$=1.80, p=0.10) and zone and month ($F_{18,42}$=0.50, p=0.90) but there was between transect and zone ($F_{3,42}$=7.40, p<0.001).

Group 2: There were no significant differences in nutrient concentrations (NO_2 (Figure 5.10), NO_3 (Figure 5.11), and PO_4 (Figure 5.12)) between the Euphrates River and the CM and transects. There were significant differences between monthly means of the NO_2 and NO_3.

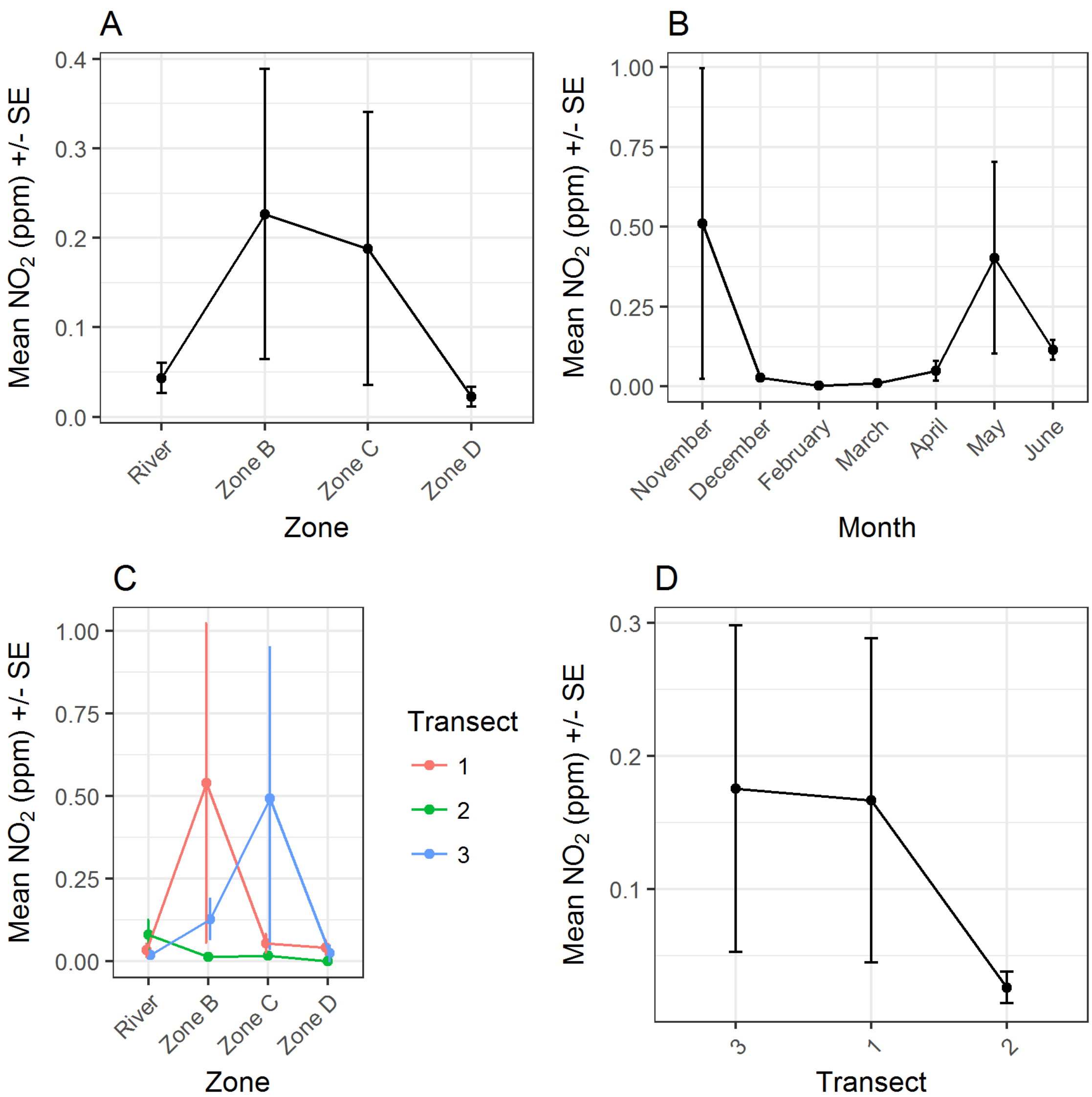

Figure 5.10. Laboratory mean ± SE (between-subjects) NO_2 in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way

ANOVA showed that there was no statistically significant interaction between transect and month ($F_{7,49}$=2.00, p=0.10) and zone and month ($F_{21,49}$=1.60, p=0.10) and transect and zone ($F_{3,49}$=2.00, p=0.10).

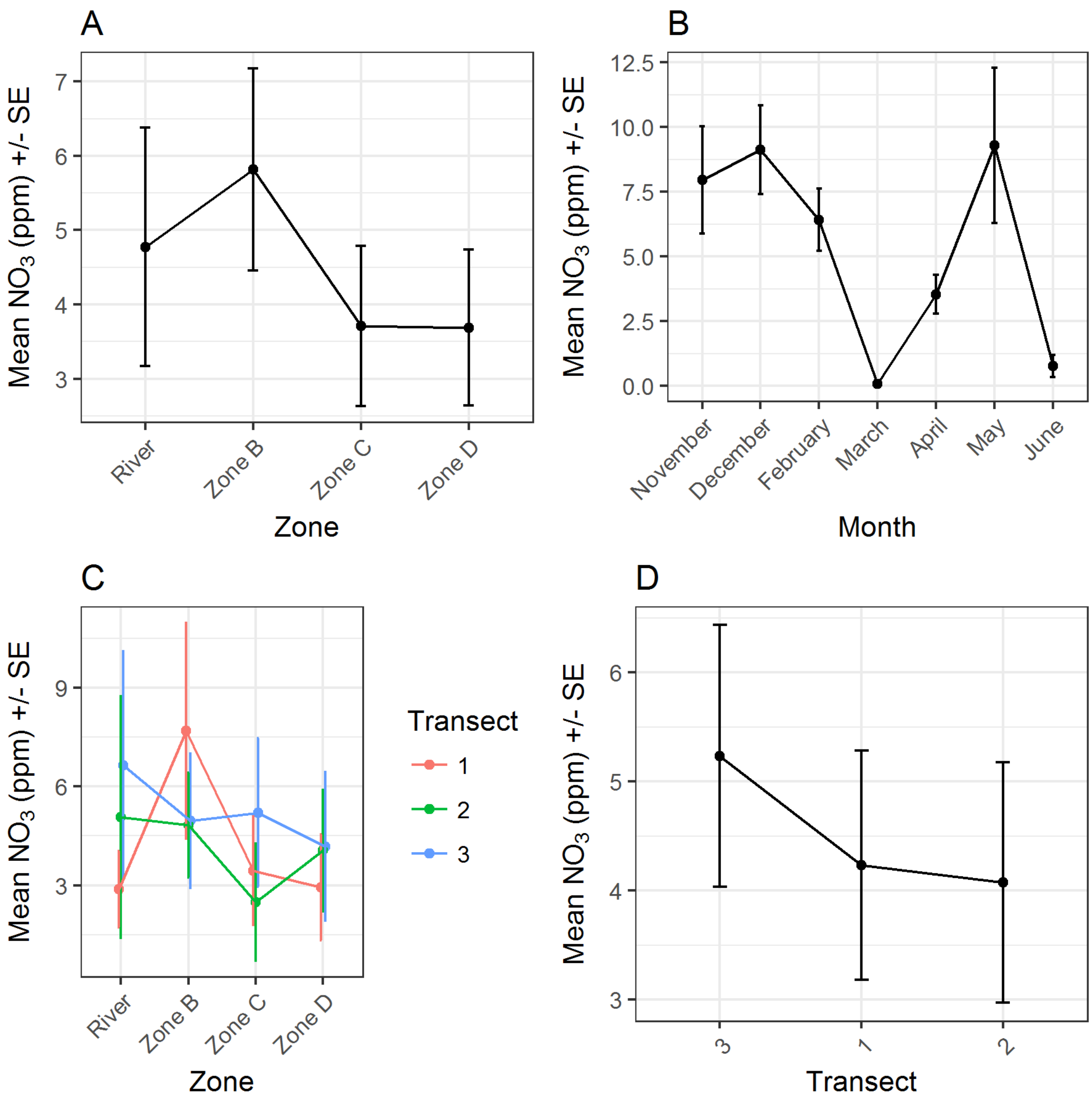

Figure 5.11. Laboratory mean ± SE (between-subjects) NO_3 in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{7,49}$=1.10, p=0.40) and zone and transect ($F_{3,49}$=2.00, p<0.01) but there was between zone and month ($F_{21,49}$=2.90, p<0.001).

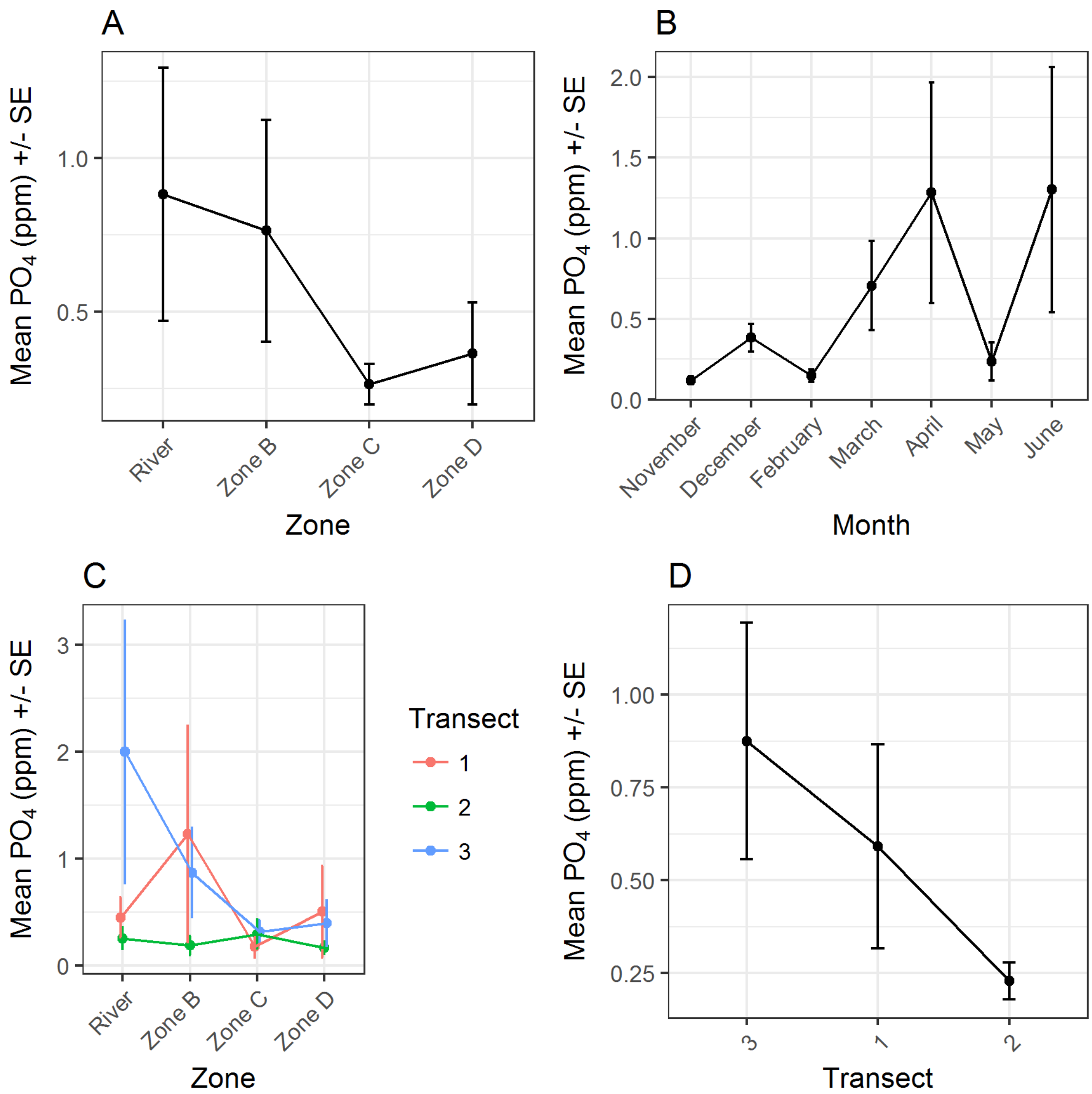

Figure 5.12. Laboratory mean ± SE (between-subjects) PO_4 in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{7,49}$=3.70, p=0.60) and zone and month ($F_{21,49}$=1.20, p=0.30) and transect and zone ($F_{3,49}$=1.50, p=0.20).

Group 3: Our analysis of anion concentrations (Na (Figure 5.13), K (Figure 5.14), Cl (Figure 5.15), Ca (Figure 5.16), and Mg (Figure 5.17)) indicated that the concentrations in the Euphrates River were less than the CM. Zone D and transect 3 had the highest means compared with zones B and C, and transects 1 and 2. N = 96.

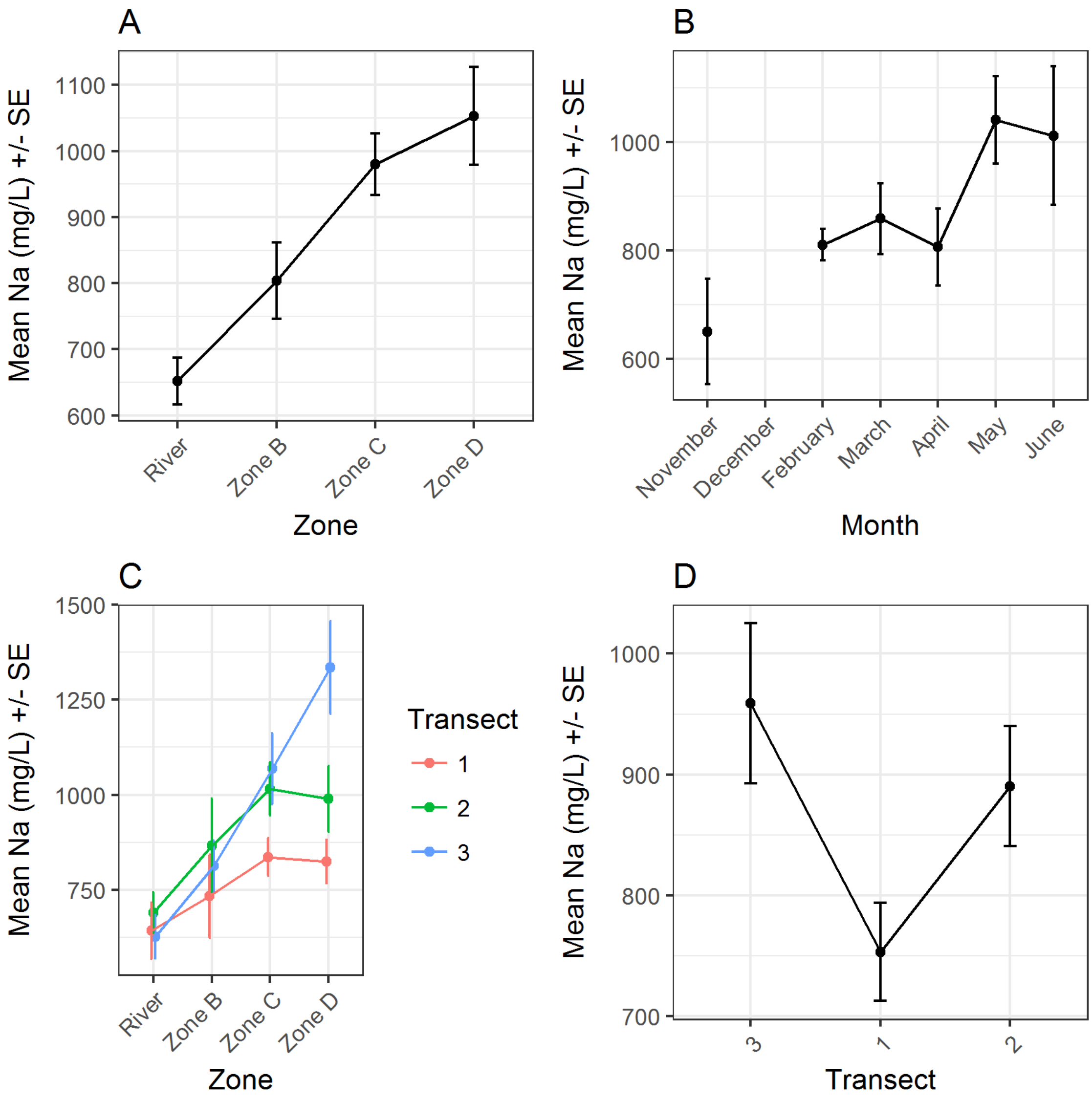

Figure 5.13. Laboratory mean ± SE (between-subjects) Na in mg/L in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 77 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{6,39}$=0.90, p=0.50) but there was between zone and month ($F_{18,39}$=2.20, p=0.02) and transect and zone ($F_{18,39}$=1.8, p=0.02).

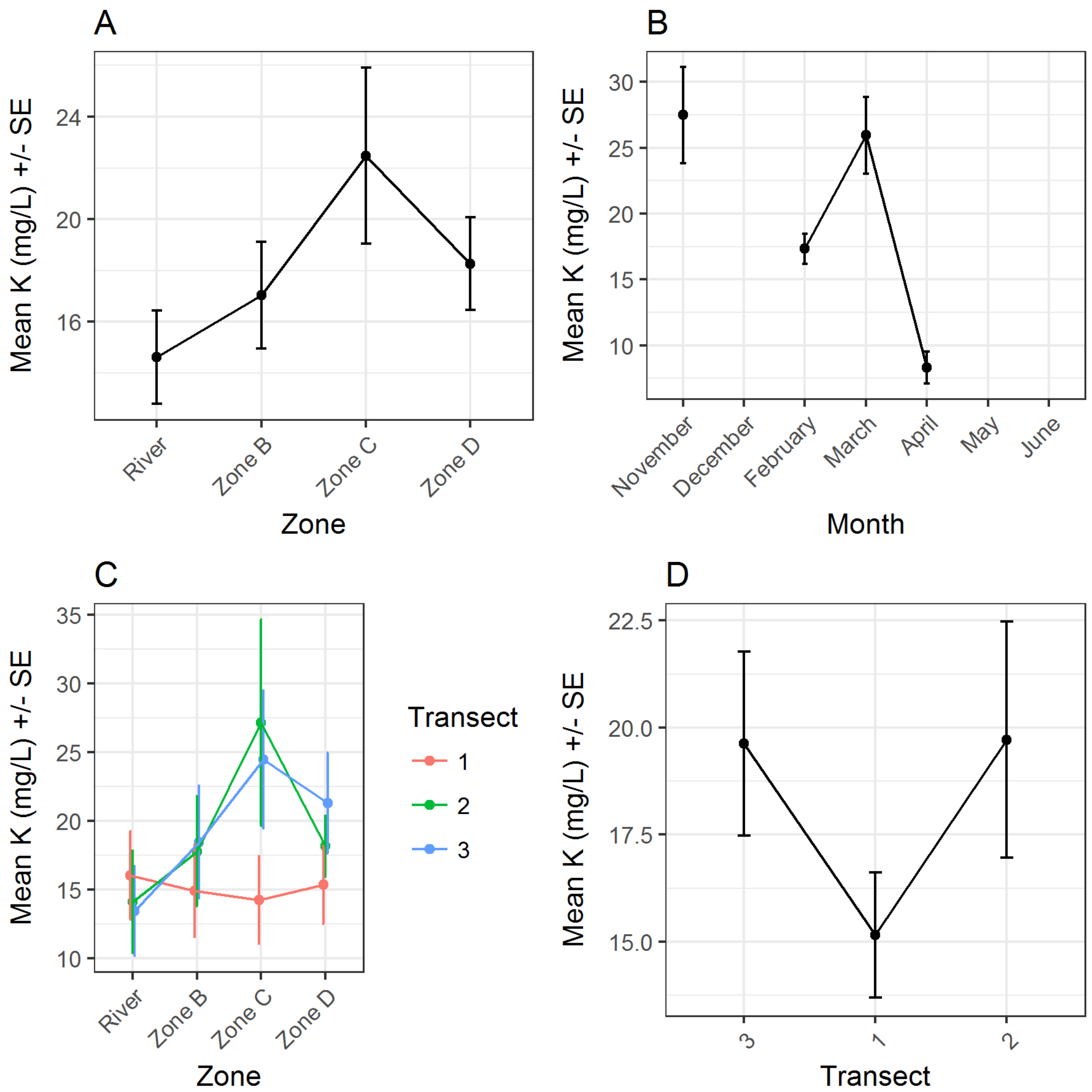

Figure 5.14. Laboratory mean ± SE (between-subjects) K in mg/L in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 53 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{4,25}$=1.40, p=0.30) and zone and transect ($F_{3,25}$=1.50, p=0.20) but there was for month and zone ($F_{12,25}$=2.70, p=0.01).

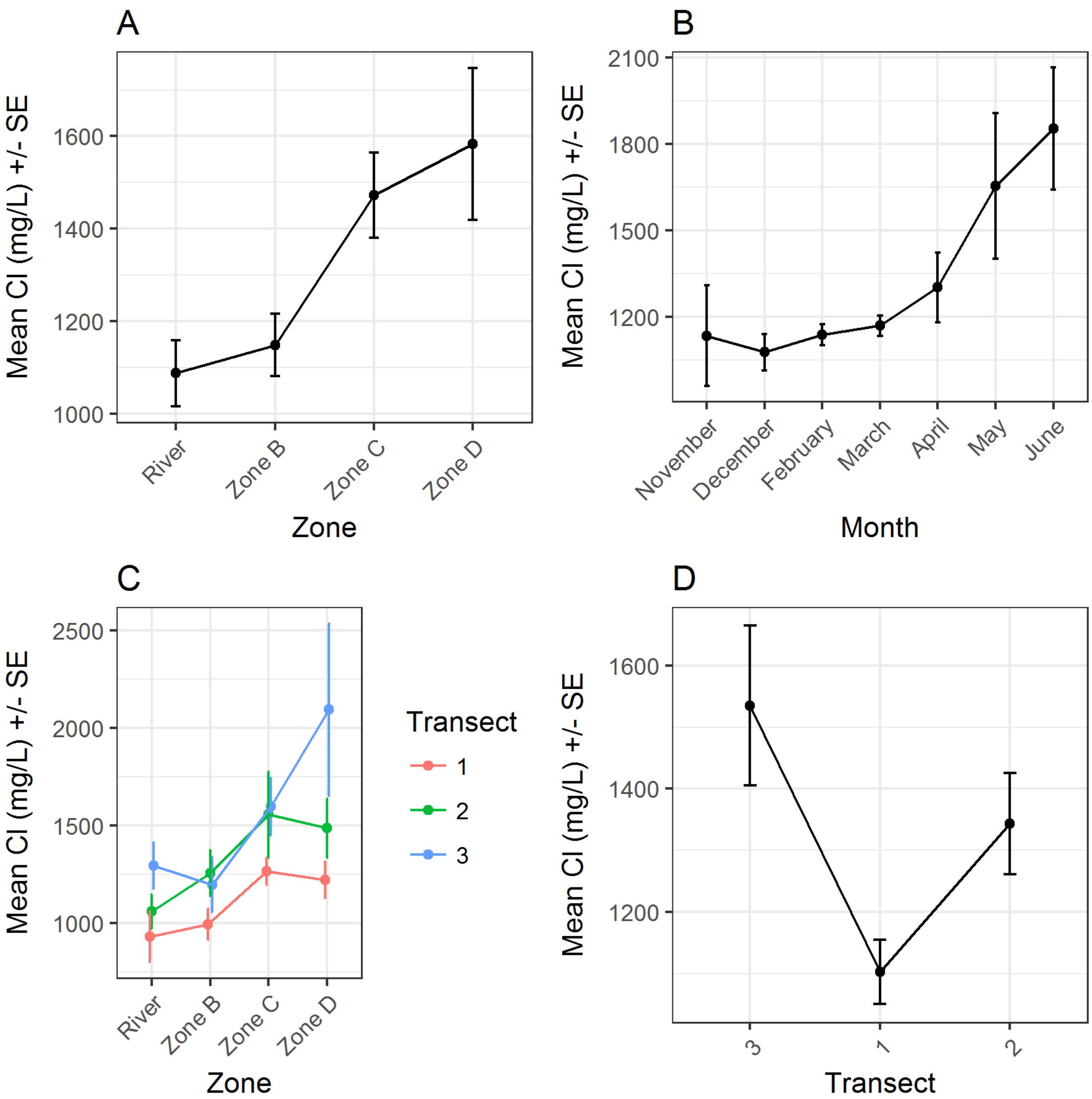

Figure 5.15. Laboratory mean ± SE (between-subjects) Cl in mg/L the CM's water from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=5.80, p<0.001) and zone and month ($F_{21,49}$=3.20, p<0.001) and transect and zone ($F_{3,49}$=8.10, p=0.01).

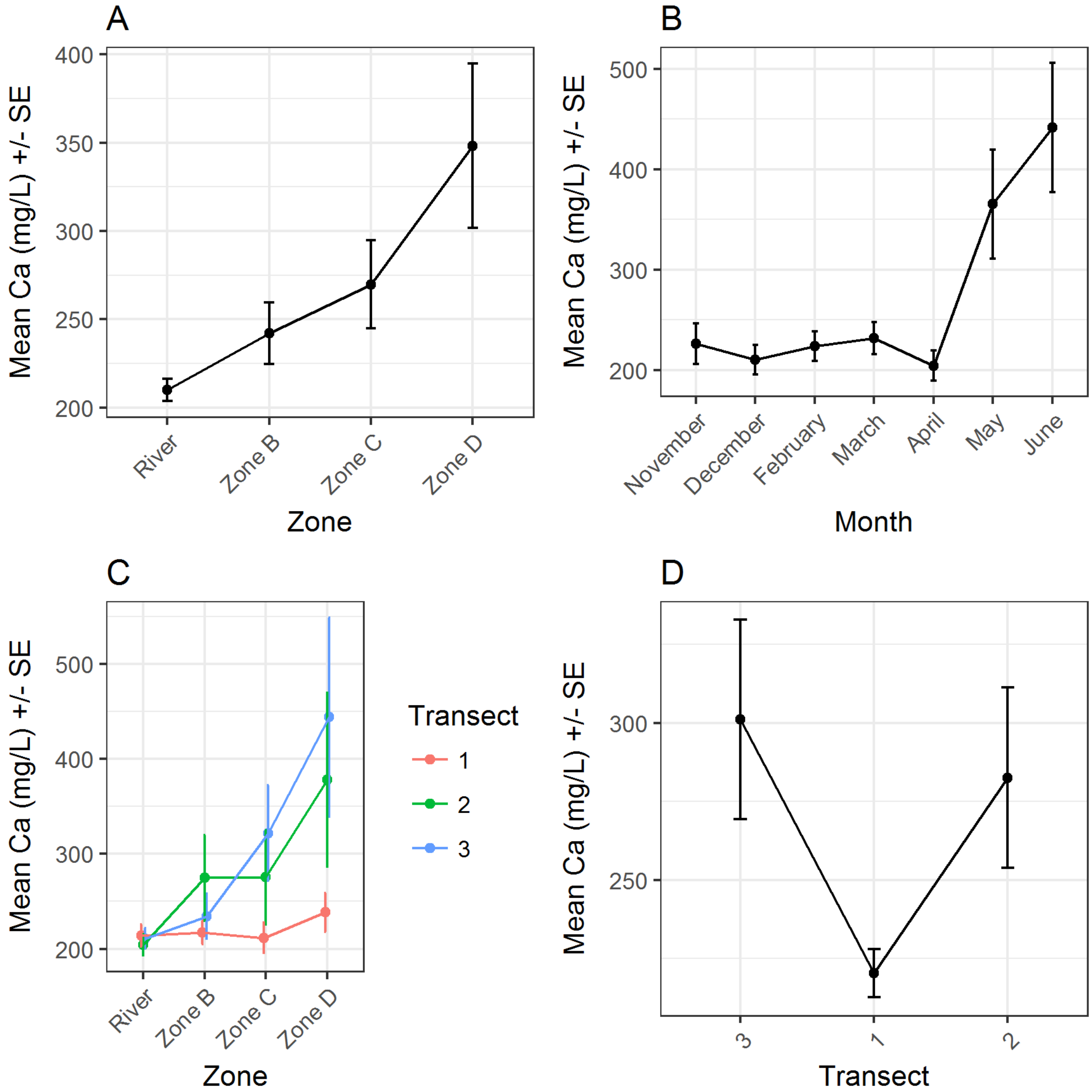

Figure 5.16. Laboratory mean ± SE (between-subjects) Ca in mg/L in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=3.50, $p<0.001$) and zone and month ($F_{21,49}$=4.00, $p<0.001$) and transect and zone ($F_{3,49}$=8.10, $p<0.001$).

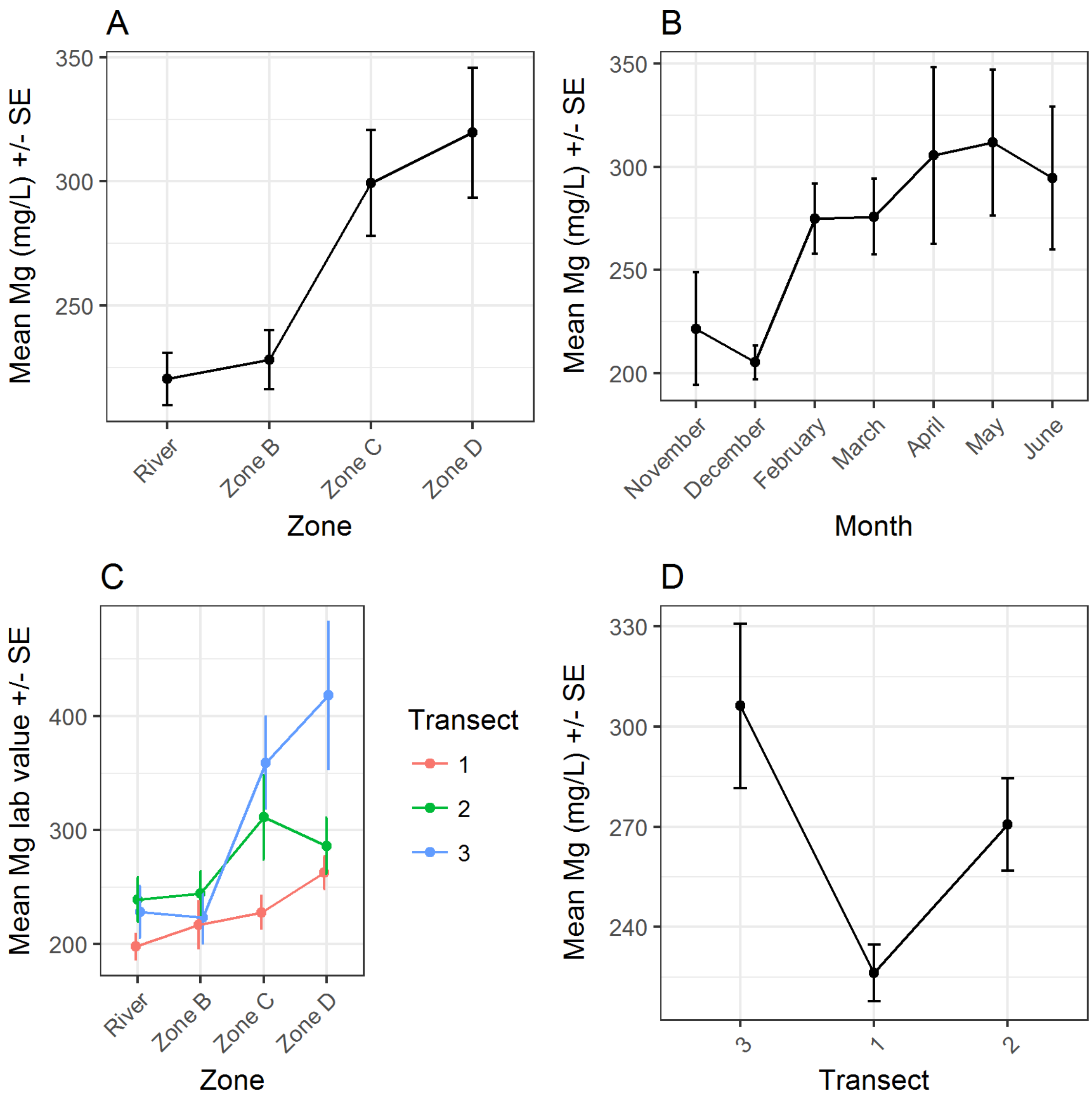

Figure 5.17.Laboratory mean ± SE (between-subjects) Mg in mg/L in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=2.40, p=0.03) and zone and transect ($F_{3,49}$=4.90, p<0.001) but not month and zone ($F_{21,49}$=1.60, p=0.07).

Group 4: Analysis of variance indicated that the main effects of zone, transect, and month were significant for all heavy metals and their interactions (Cu Figure 5.18, Ni Figure 5.19, Pb Figure 5.20, Cd Figure 5.21, and Zn Figure 5.22). The exception was the interaction between zone and transect, which were not significant for all metals. Zone and month interaction was also not significant for Zn (Figure 5.22). In general, the mean ± SE for all metals was higher in the marsh compared to the river. Within the marsh zone D has the highest metal content.

On the other hand metal content were significantly higher in transect 3 compared to transects 1 and 2.

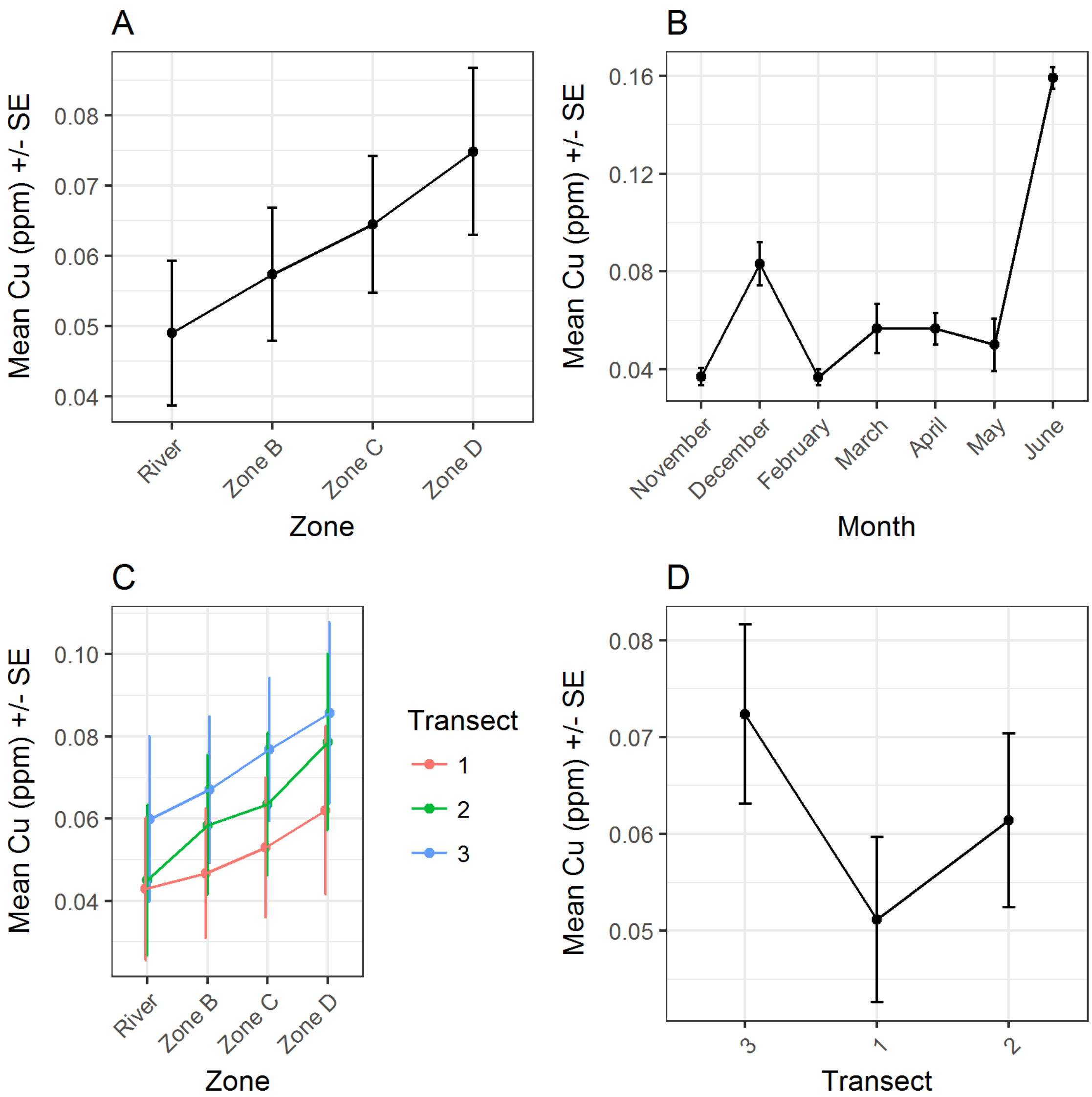

Figure 5.18. Laboratory mean ± SE (between-subjects) Cu in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=6.90, p<0.001) but not zone and month ($F_{21,49}$=1.00, p=0.50) or transect and zone ($F_{3,49}$=0.20, p=0.90).

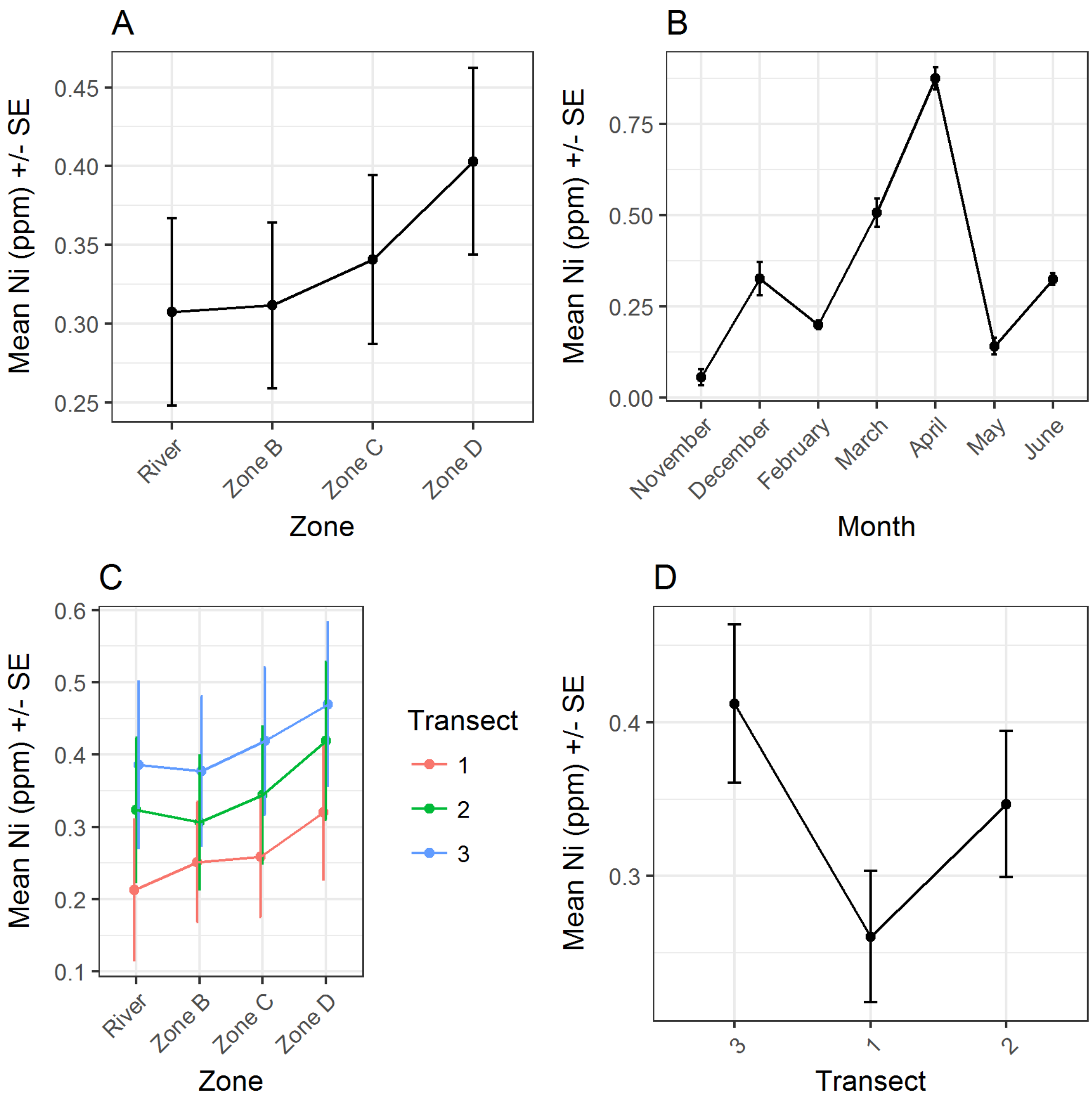

Figure 5.19. Laboratory mean ± SE (between-subjects) Ni in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=9.90, p<0.001) and zone and month ($F_{21,49}$=4.90, p<0.001) but not transect and zone ($F_{3,49}$=0.80, p=0.50).

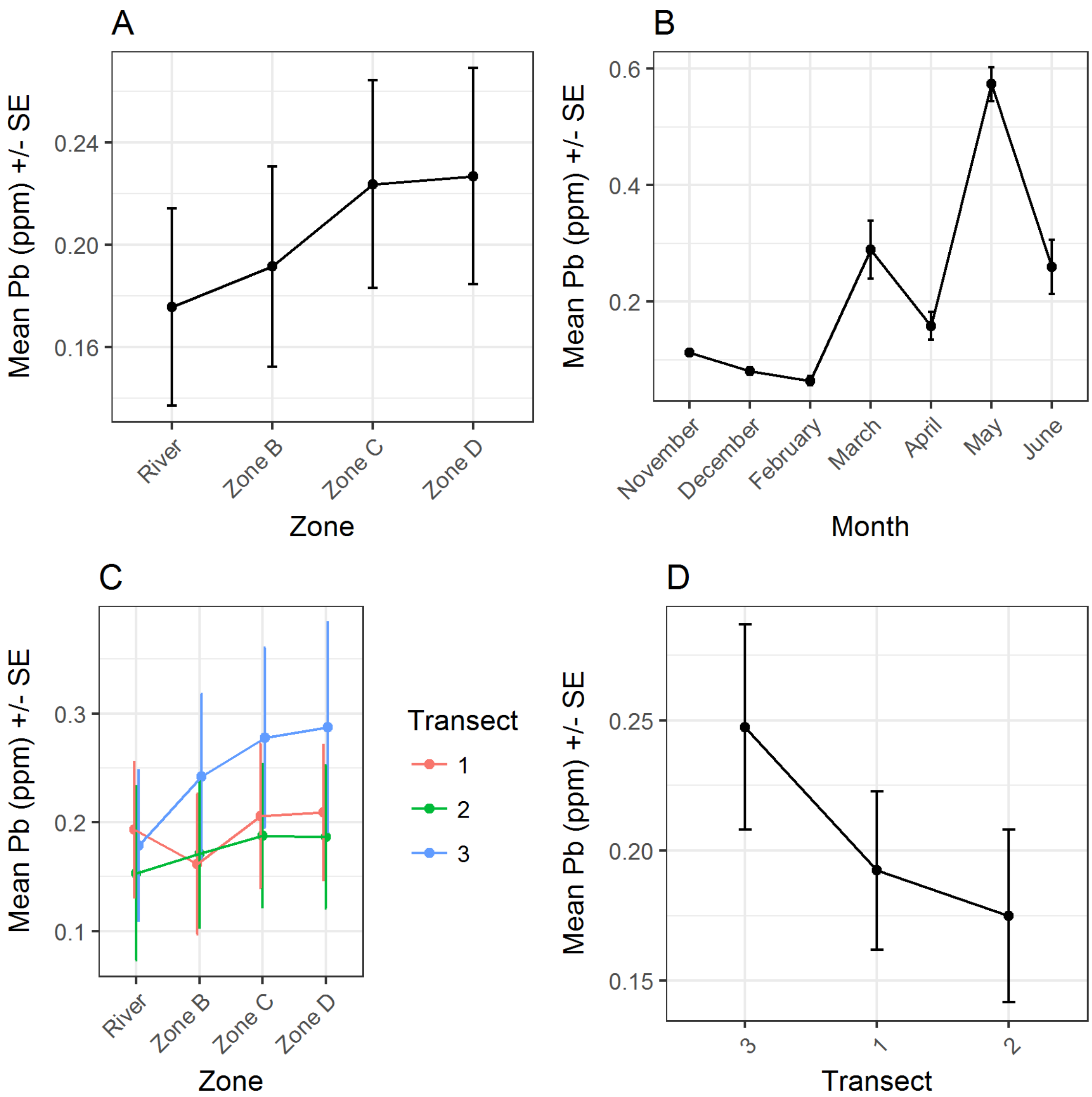

Figure 5.20. Laboratory mean ± SE (between-subjects) Pb in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=2.50, p=0.02) but not zone and month ($F_{21,49}$=1.20, p=0.03) or transect and zone ($F_{3,49}$=1.30, p=0.30).

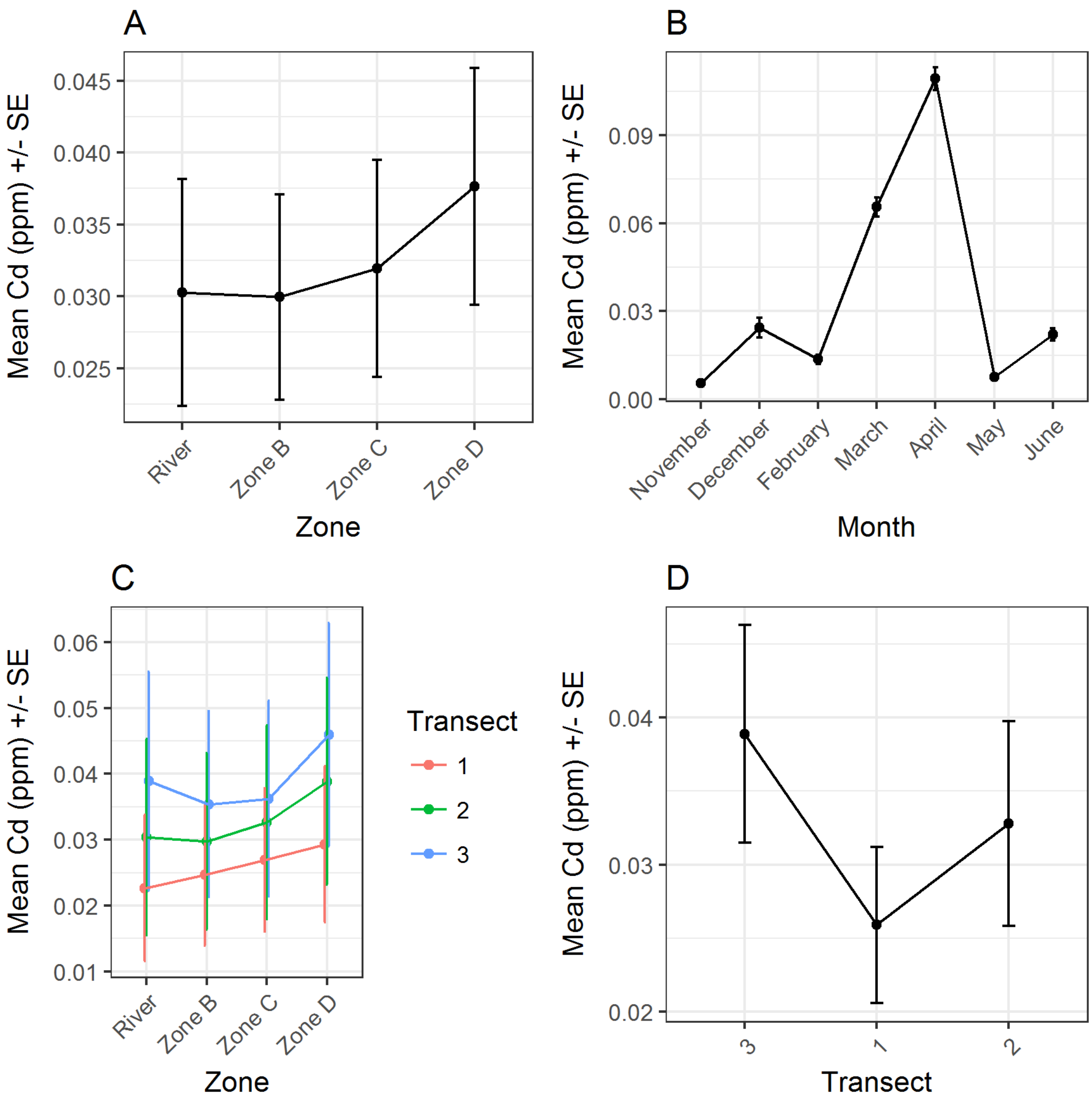

Figure 5.21. Laboratory mean ± SE (between-subjects) Cd in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was a statistically significant interaction between transect and month ($F_{7,49}$=19.30, p<0.001) and zone and month ($F_{21,49}$=3.70, p<0.001) but not transect and zone ($F_{3,49}$=0.90, p=0.40).

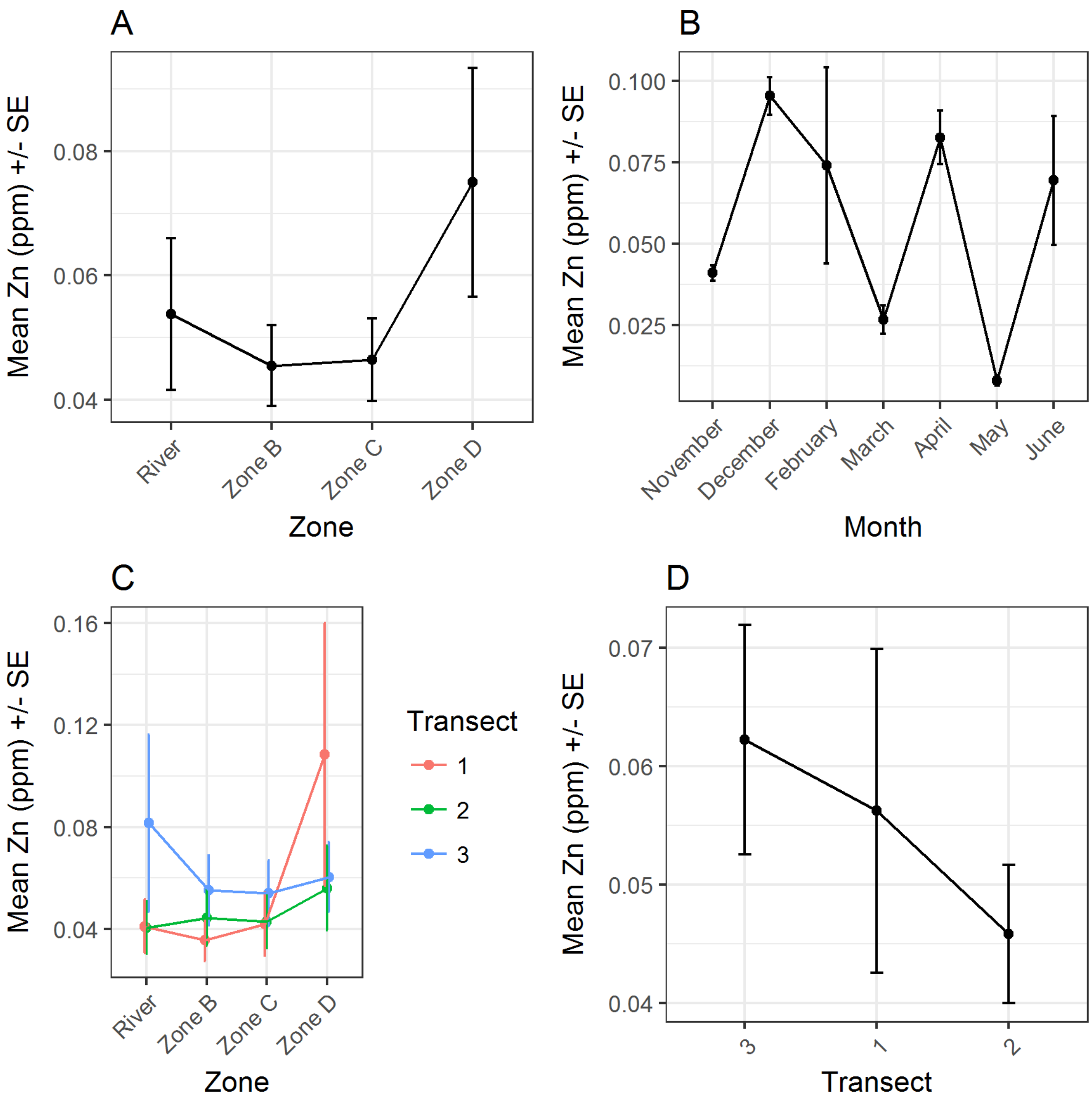

Figure 5.22. Laboratory mean ± SE (between-subjects) Zn in in ppm in the CM for A) zone; B) month; C) zone and transect; and D) transect from November 2013 to June 2014. N = 96 samples across entire study period. A two-way ANOVA showed that there was not a statistically significant interaction between transect and month ($F_{7,49}$=1.70, p=0.10) and zone and month ($F_{21,49}$=1.30, p=0.20) but there was for transect and zone ($F_{3,49}$=1.80, p=0.20).

5.4. Discussion

Salinity in the Mesopotamian Rivers (Tigress and Euphrates) increased significantly from 1970 to 2008 as a result of the huge reduction of the water discharged in both rivers (from 84.6 x10^9 m^3 to 13.8 x10^9 m^3 respectively) (Al-Maarofi, Douabul and Al-Saad, 2012). Sequentially, salinity of the Iraq's marshlands has increased dramatically (from 0.4 psu to 2.5 psu in 1980, and then 1.1psu 2005 to 2008 (Al-Maarofi, 2015) and the water has changed from fresh to brackish water (Nature Iraq, 2006b; Al-Ansari, Knutsson and Ali, 2012). Salinity in the marshlands is affected by 2 factors: water quantity (historical peak of water from April – June, and low level from September – November (Al-Saad *et al.*, 2010) and the second factor is evaporation (high evaporation and low rain in the Summer). Dam construction upstream of the rivers, pollution, increasing agricultural activities, evaporation, and the tidal effect of the Shatt Al Arab in Basra province are the reasons for the increased salinity levels in the Iraqi southern marshlands (Nature Iraq, 2006b; Al-Ansari and Knutsson, 2011; Al-Maarofi, Douabul and Al-Saad, 2012). Our results indicated that salinity concentration inside the CM is significantly higher than the Euphrates River, which is the main source of water into the CM, and it is higher in the summer compared to the winter. Moreover, the concentration of salinity was higher when the water went deep inside the marsh (e.g. zone D vs. zones B and C). Some previous studies indicated that CM could be influenced by the marine tide of the Shatt Al Arab (Nature Iraq, 2006b; Al-Saad *et al.*, 2010; Al-Maarofi, Douabul and Al-Saad, 2012), which could be one of the main sources of salinity in the marsh. Our results show that there are still high levels of salinity within the CM but they cannot be explained by the marine tide as the current hydrology situation and existence of the newly constructed soil embankment between Chibayish City and Modina City largely prevents water from re-entering the CM in this way.

Dividing the area of study into three transects helped to confirm our findings: the Euphrates water comes from the west and then crosses the CM towards Chibayish City in the east. Our results clearly indicated that transect three (located immediately before Chibayish city) had the highest concentration of water salinity compared with transect one (located in the middle of Chibayish city) and transect 2 (located after Chibayish city). If the marine tide was a major source of salinity, we would have expected the opposite pattern to be true. Analysis of major ions could provide additional evidence of increases in the salinity concentration. Major ions concentrations in the CM increased significantly from 2005 to 2008 (Douabul *et al.*, 2012). The same study has indicated that chloride ion concentrations were higher and fluctuated more than the calcium and magnesium ions especially in the summer. Our results have indicated the same findings, in which major ions concentrations in the CM were higher in concentration than in the Euphrates River.

Heavy metals could naturally occur in the water. Increasing metal concentrations could cause an acute or chronic toxic problem on the ecosystem structure, wildlife, and food chain, which can affect negatively on the health, diversity, and distribution of species that use the aquatic ecosystem including human (Al-Saad *et al.*, 2010; Al-Maarofi *et al.*, 2013). Historically the Mesopotamian marshlands used to be an excellent sink for pollutants and heavy metals (Richardson *et al.*, 2005; Nature Iraq, 2006b). However, the marshlands have faced 13 years of desiccation from 1990 to 2003 (Richardson and Hussain, 2006) and this desiccation caused a negative impact on the marshlands' ecosystem and huge changes to environmental variables, which fragmented the historical homogeneity of the marshlands system (Razoska, 1980) into several separated systems (Al-Maarofi *et al.*, 2013). The CM's hydrology changed dramatically after 2003, and the area was declared as a protected area (Alwash *et al.*, 2009). Thus, it is crucial to evaluate heavy metals mobilization and examine whether the CM could act again as a good sink for heavy metals after the re-flooding and subsequent embankment of the Euphrates River. Water quality of the Marshlands after restoration was classified as bad quality (Al-Ansari, Knutsson and Ali, 2012). Monitoring of heavy metals and studies after re-flooding of 2003 have indicated that the Central Marsh has extremely high levels of heavy metals and is considered as a major source of heavy metals to the Shatt Al-Arab in the Basrah province compared to other marshes (Haweiza and Hammar marshes) (Al-Saad *et al.*, 2010; Al-Maarofi *et al.*, 2013). Although our results agreed with the finding of the previous studies regarding the high-level concentrations of the heavy metals in the Central Marsh; however, we consider the CM must now be a minor source of heavy metals to the Shatt Al Arab owing to the embankment, which prevented water from the CM reaching the Shatt Al Arab during the survey time of this study. High concentrations of the heavy metals in transect 3 (which is located before Chibayish City) and high concentrations in zone D (which is the furthest away zone from the Euphrates River) clearly indicate that the heavy metals must be coming from upstream Chibayish City in the West and are then accumulating in the Central Marsh in Zone D with little chance of passing the embankment. Moreover, our results indicate seasonal variance of heavy metal concentrations in the CM with higher levels in summer. This is unsurprising as water levels are lowest in the summer.

Nutrient enrichment and eutrophication are considered as one of the major problems that face the aquatic environment globally (Smith, 2003). Water from the Mesopotamian marshlands and Shatt Al Arab in Basra province are facing the same problem (Al-Saad *et al.*, 2010; Al-Maarofi, 2015). International conventions such as OSPAR and HELCOM have indicated the need to reduce nutrient input to the global fresh water and marine environments. Although there is a lack of long-term evidence of performance of the wetlands as a sink for nutrients before going to rivers and marine systems, using wetlands to reduce nutrient concentrations is commonly used globally (Land *et al.*, 2016). The same study indicated that the removal rate of total Nitrogen (TN) and Phosphorus (TP) is significantly dependent on Hydrological Loading Rate (HLR), temperature, and concentration in the inlet of the system. Wetlands with controlled HLRs and water pulses are more efficient at removing TP than other wetlands. Nutrient concentrations in the Mesopotamian marshlands after the re-flooding in 2003 were higher than historical records due to sediment organic matter contents that resulted from aquatic plant decomposition and nutrients being liberated from the soil to water as a rehabilitation action after the re-flooding (NO_3, NO_2, and PO_4 concentration were 0.030, 0.055, and 0.22 µg/L respectively in 1988, and 0.680, 49.50, 3.60 µg/L respectively in 2006 (Al-Saad *et al.*, 2010). However, other studies suggested that the concentration of nutrients in the marshlands is declining over time after the re-flooding, which indicates the important role of the marshlands in removing the extra concentration levels of the nutrients (Douabul *et al.*, 2012). More investigation is needed in order to provide strong evidence of this important role of the CM and to estimate the removal rate of the nutrients.

Urban runoff, agricultural activities and pollution upstream of Chibayish city, evaporation in the summer, and historical desiccation of the area are likely to be the most important sources of salinity, major ions, heavy metals, and nutrients in the CM. In addition, the existence of the soil embankment made the CM the terminal site for all Euphrates water that comes from the west of Chibayish city when water depth in the Euphrates is low. As a result, over time accumulation could increase the concentration of major ions, salinity, and heavy metals in the CM, and decrease the filtration ability of the marsh and its role as a sink for pollutants and salinity. High concentrations of salinity could have huge impacts on locals and wildlife. Heavy metals, due to their high concentrations in the water of the CM, could be accumulated in the muscles of fish and milk of water buffalo and that could affected local people’s health, as they heavily rely on the fish and milk as main sources of food. In addition, high levels of heavy metals could have negative impacts on the wildlife and the ecological function of the marsh, especially the 125-bird species (Fazaa, Dunn and Whittingham, 2017) and the globally endangered soft shelled turtle *Rafetus euphraticus* (Fazaa, Dunn and Whittingham, 2015) that use the habitat of the CM. Although the CM is currently facing a critical situation due to water scarcity, it appears to still have the ability to remove the extra level of nutrients concentration. However, more intensive surveys are required to provide strong evidence for this role, and to evaluate whether the CM can continue play this important role under the current levels of water scarcity. The question is: how long the site can withstand the current challenges?

Chapter 6. Vulnerability of the Central Marsh to climate change and implications for resilience planning in Iraq

6.1 Introduction

Climate change has become a global problem and is predicted to cause extreme and unpredictable environmental events in the future (Pachauri *et al.*, 2014). Interactions between changes in the climate system and socio-economic processes (including mitigation of and adaptation to climate change) are drivers of exposure and vulnerability to climate change (IPCC, 2007). Exposure to climate change is the degree of stress that results from climate variability such as changes in mean temperatures, levels of precipitation, sea level, and frequency of extreme events. The ability of ecosystems and species to respond and adapt to the negative effects of climate change are defined as vulnerability (Gitay *et al.*, 2002; Hannah, Midgley and Millar, 2002; Smithson, 2002; Fischlin *et al.*, 2007). In addition, the vulnerability of an ecosystem can be measured by evaluating its physical, social, and economic aspects, and sensitivity (Stocker, 2014). The ability of ecosystems to convey fundamental services to society is already under stress and the problem will be more complicated in the future under climate change impacts (Mooney *et al.*, 2009). Recently, direct impacts of climate change have been defined as a strong, dominant cause of biodiversity loss at the local and global levels in this century (Thomas *et al.*, 2004; Stocker, 2014). There are three levels of climate change stresses that act upon biodiversity: stresses that affect individuals and populations, stresses that affect biological communities and stresses that affect ecosystem functioning. As a consequence, almost 20–30% of fauna and flora species are at high risk of extinction due to the rising of global mean temperatures 2–3°C above pre-industrial levels (Fischlin *et al.*, 2007; IPCC, 2007). Increasing human populations will themselves be vulnerable to climate change, and human adaptation responses are likely to be an additional indirect negative impact on biodiversity and natural ecosystems (Pacifici *et al.*, 2015). Countries' exposure to climate change is non-uniform and varies depending on the region and local area (IPCC, 2007). Thus, measuring exposure and prioritising the most vulnerable areas and species to climate change at the country level is crucial and is a matter of urgency (Julius *et al.*, 2008; Benioff, Guill and Lee, 2012; Stocker, 2014). Two hundred and twenty natural ecosystems including the Mesopotamian Marshlands were surveyed from 2005 to 2010 and recorded as key biodiversity areas (KBAs) in Iraq (Nature Iraq, 2017). The CM is one such KBA site in Iraq. However, the site has a specific interest from the Iraqi government due to high levels of interaction between local people and nature. Thus, the government declared the site as the first national park and protected area in the country (Alwash *et al.*, 2009; Pearce, 2013).

In addition to the threats that face the CM discussed in Chapter 1, climate change could be an additional strong stressor that could make the future of the marshlands and CM much worse. Despite the global alarm regarding impact of climate change on natural systems there is a lack of information at the national level in Iraq. Exposure, vulnerability, and adaptability at the level of sites and species are the most frequently mentioned impacts of climate change (Pacifici *et al.*, 2015). There are several key factors that can be used to determine and evaluate the vulnerability of an ecosystem to climate change impacts at the site level such as: existence of endangered species, people being part of the ecosystem, existence of resources for human livelihoods, ecosystem services (a degraded ecological base makes the system more vulnerable to climate change), dependence (overdependence on a climate-sensitive sector such as fisheries, water resources, agriculture makes the system more vulnerable to climate change), level of economic wealth and income, weak socio-cultural (e.g. social conflicts), poor health conditions, and infrastructures and technological (skill-related) and human resources (Füssel, 2007; Stocker, 2014). A multi-dimensional framework has been suggested for vulnerability analysis. In addition, vulnerability has been defined as a function of exposure, sensitivity, and adaptability within social and ecological systems (Turner *et al.*, 2003). There is no universally accepted methodology used to evaluate vulnerability of species to climate change. However, four approaches were explained in Pacifici *et al*. (2015) (correlative, mechanistic, trait-based, and combined). Expert explanation and assessment could be an additional approach that could provide an estimated evaluation for ecosystems and species vulnerability. Trait-based vulnerability assessment (TVA) is the most commonly used methodology and easier than other approaches because it does not require large data sets or complex modelling. Availability of data is very important when choosing suitable methods to evaluate vulnerability.

Given the lack of information on the impact of climate change on Iraq, and especially the marshlands, our study aims to evaluate the impact of climate change on the CM as a case study. We had three aims: (i) to evaluate the exposure of the CM to climate change by mapping past and future changes in air temperature and rainfall both for the marshlands and in other regions in Iraq; (ii) to predict the impact of climate change on socio-economic and biodiversity receptors (birds as key species in the CM) in the CM; and (iii) to make policy suggestions for future national resilience planning to tackle climate change in Iraq based on (i) and (ii) as a case study.

6.2 Materials and Methods

6.3 Evaluating exposure of the CM to climate change by using past and future changes in air temperature and rainfall both for the marshlands and in other regions in Iraq.

Baghdad (in the middle of Iraq) is projected to undergo a mean increase of +3°C in average temperatures with southern areas potentially undergoing a larger increase still (Pachauri *et al.*, 2014; Ministry of Health and Environment, 2016). Precipitation in the south and west of Iraq is due to remain largely the same until 2100 (Osman, 2017). However, as climate change projections may not be uniform, we also wanted to use historical data to give some indication of how temperature might differ for the south of Iraq and the CM specifically.

Temperature and rainfall data were made available to us from six meteorological stations and were used to calculate the mean differences in the historical data between the six stations. Summary details of the data (years made available) and sites are given in Appendix 6 Table 6.6 but briefly, data were available from 1937-2014 across most stations. The definition of climate change is any changes within a 30-year timespan (IPCC, 2007) and so these data should be representative of any historical changes.

Temperature and rainfall data across different time spans were used to calculate means in the following way: (i) the daily mean was calculated as the midpoint between the minimum and the maximum temperature for each day; (ii) the monthly mean was calculated by averaging daily means for n days across each month; (iii) the average of the 12-monthly means was then used to give an annual mean; (iv) the mean for the whole record was calculated as the mean of yearly temperatures across n years. In each case error was calculated for the corresponding level of the hierarchy (i.e. if there was data available for 30 years then the error was calculated based on 30 data points, one for each year). A one-way ANOVA in Minitab 17 (Minitab Inc., 2010) was used to investigate differences between the mean temperature and rainfall values from the six stations.

6.4 Predicting the impact of climate change on socio-economic and biodiversity receptors (birds as key species) in the CM:

a. At the site level:

We designed our methodology to collect data that can help to evaluate the vulnerability of the CM as “a socio-ecological system” at the site level. We used the CM’s socio – economic data, ecosystem services data, and ecological data that is published in the following literature (Nature Iraq, 2006a, 2017; Abid *et al.*, 2007; Fazaa, Dunn and Whittingham, 2015, 2017) to highlight key factors/characteristics that can be used to determine and evaluate the key vulnerability of the CM's ecosystem to climate change impacts at the site level. The factors/characteristics evaluated were chosen based on the IPCC 5th National Report (Chapter 19) guidelines (Oppenheimer *et al.*, 2014). These were split into socio-economic characteristics (including water quality and ecosystem services) and ecological characteristics. Following the IPCC framework we cross-checked these characteristics according to Box 19-2 definitions p1048 and criteria for evaluating key vulnerabilities p1051 (see Figure 6.1, which illustrates the interaction of the climate system with evolving characteristics of socioeconomic and biological systems (exposure and vulnerability) to produce risk). Presence of these characteristics makes the site highly susceptible to climatic hazards and reduces its ability to cope and adapt to climate change.

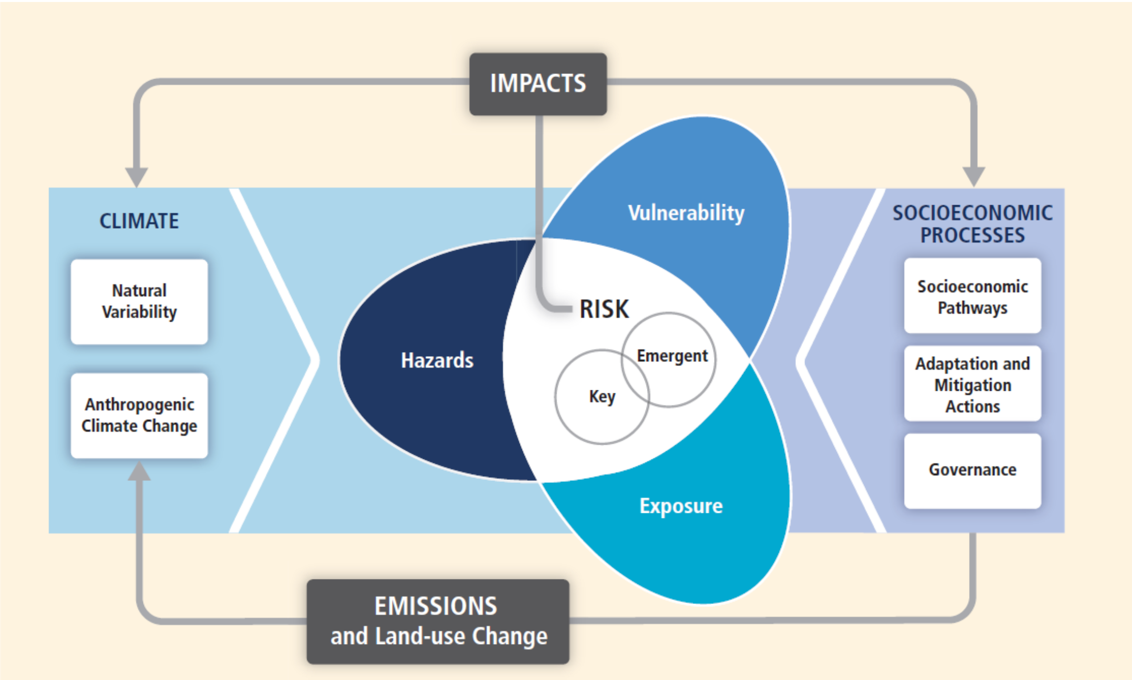

Figure: 6.1. Schematic of the interaction between the physical climate system, exposure and vulnerability producing risk (after Oppenheimer et al 2014). The figure visualises the different terms and concepts in a similar way that is used in this chapter and thesis

a. *At the species level:*

Birds have been well-studied in the field of climate change impacts (Pacifici *et al.*, 2015). A large percentage of studies have focused at local scales but few at the global level (Pacifici *et al.*, 2015). Birds were identified as one of the important key fauna that use the CM's habitat (Fazaa, Dunn and Whittingham, 2017; Nature Iraq, 2017). 125 resident and migrant bird species were recorded in the CM (Fazaa, Dunn and Whittingham, 2017), which were assessed for vulnerability to climate change at the species level. We followed a trait-based vulnerability assessment adapted from Foden *et al.* (2013) where we estimated vulnerability across several traits and sum the number of times species are flagged as vulnerable across such traits. We used the trait-based vulnerability assessment because we did not have sufficient data to follow other potential methods such as correlative and mechanistic approaches. Foden *et al.* (2013) used the following 7 traits to assess both sensitivity and adaptability in her analysis:

1. Does the species have specialised habitat and/or microhabitat requirements?
2. Is the environmental tolerance at any life stage likely to be exceeded due to climate change?
3. Does the species depend on environmental triggers to initiate life stages?
4. Does the species depend on interspecific interactions likely to be affected by climate change?
5. Is the species rare?
6. Does the species have poor dispersal ability?
7. Does the species have poor evolvability?

As Foden *et al.* (2013) examined species at the global level and had more information and data on traits, we sought to adapt her approach using some analogous criteria. We used endemism to the CM as a measure of local rarity (similar to Foden *et al.* 5th criterion), we used whether the bird was a migrant or not as a measure of dispersal ability (similar to Foden *et al.* 6th criterion), we used temperature and precipitation values across the species' global range (similar to Foden *et al.* 2nd criterion) and we used number of habitats within the CM (similar to Foden *et al's* 1st criterion). We did not have sufficient information to use Foden *et al's* 3rd and 7th criteria. We explain how we used our chosen traits more fully below.

Our procedure was as follows:

i) We downloaded global range map shapefiles for every bird species in the CM from the BirdLife International website (BirdLife International and NatureServe, 2011). 100 bird species out of 125 found in the CM had BirdLife range maps that overlapped with the CM.

ii) We calculated the mean maximum temperature in the CM. To do this we used temperature data from 1941 – 2014 from the closest (Nasiriyah) meteorological stations, and we calculated mean rainfall using data from 1960 – 2014 from the same station. Then we used projections for the Iraq in its entirety for the future temperature and precipitation scenarios.

iii) For each bird we calculated the percentage of its global range that intersected the CM to give a measure of endemism (how much of each species' global geographical range is found within the CM; the more endemic the species, the greater the vulnerability to climate change within the CM). The procedure to create the range data was as follows:

1. Project the global range shapefiles for each species to a worldwide projection (equal area); 2. Calculate the area for that shapefile; 3. Clip the global range shapefiles by the CM shapefile for each species; 4. Calculate the area for the CM shapefiles; 5. Calculate endemism as follows: (CM area/global area) *100.

The endemism percentages were between 0.003 – 0.009. We categorized the percentages into three groups and gave a score to each group as follows: 0.000-0.003 = 0, 0.004-0.006 = 0.5, 0.007-0.009 = 1.

iv) We summarised each species' environmental tolerance globally (we calculated the minimum, maximum and mean temperature, and rainfall from across its range). We compared our environmental tolerance values with our forecasted mean rainfall and mean of maximum temperature projections within the CM. Temperature and precipitation relating to the global ranges of each of CM bird species were downloaded from www.worldclim.org (www.worldclim.org/bioclim, 2014) and the shapefiles were downloaded from Birdlife International (BirdLife International and NatureServe, 2011). All data were at a 10 arc minutes resolution.

The procedure to calculate each species' global environmental tolerances was as follows:

1. Extract the shapefiles from the birdlife data for each species in the CM; 2. Extract monthly global precipitation and temperature data from the period 1950-2000 (current conditions) and average to create mean raster files for each of the 12 months; 3. Average across the 12 months to give 1 final raster file for precipitation and temperature respectively; 4. Clip each final raster file by each species' global range shapefile; 5. Extract the maximum, minimum, range, mean and standard deviation of temperature or precipitation found within each species' global geographical range.

The global arithmetic range of maximum temperature for the bird species was between 24 – 31.4°C. We categorized the mean of the maximum temperatures into three groups and gave a score for each group as follow: 24-27 = 1, 28-31.4 = 0.5, and >31.4 = 0. Mean rain precipitation ranged between 20mm – 105mm. We categorized the arithmetic range into three groups as follows: 20-49 = 0, 50-79 = 0.5, 80-105 = 1 after comparing with mean projected precipitation values for 2050 and 2100.

v) We recorded the number of global habitats (level 1) for each bird species from the Birdlife International website. (http://www.birdlife.org/datazone/species/factsheet/22678719/additional), and then calculated the percentage of those habitats found within the CM for each species in the CM (the larger the percentage the greater the vulnerability). We categorized the habitat percentage into three groups to make a vulnerability score: 0-8.9 = 0, 9-17.9 = 0.5, 18-25 = 1. This differs from the endemism score in that some bird species might have large global ranges but with specialised habitat requirements (large Extent of Occurrence range but smaller Area of Occupancy ranges). Thus, we were trying to separate these two scenarios.

vi) We classified resident species as vulnerable and gave a score of 1 vs. migrants as not vulnerable and score of 0. Migrants were classified as less vulnerable than residents because in the context of the CM, they are more mobile and likely to disperse further distances, allowing them to seek out alternative habitats if the CM becomes uninhabitable. That is not to say that resident species cannot disperse away from the CM at all, for example there are other marshes nearby, which have the same suitable habitat.

vii) Then, for each of our scores from steps iii-vi, we added up the number of times a species was classified as 'vulnerable'. We made a final list of vulnerability scores as follows: total scores of 0-1 = 'less vulnerable', 2-3 = 'somewhat vulnerable' and 4-5 = 'highly vulnerable'. All factors were given equal weighting. We recognise that giving equal weighting to diverse and speculative factors in this way might be considered a weakness.

6.4.1 Informing policy suggestions for future national resilience planning to tackle climate change in Iraq

We framed our suggestions using i) UN 'business as usual' (BAU) data; ii) CO_2 emissions data from Iraq (UN Statistics Division, 2017);and iii) data from Iraq's initial national communication (INC) that was submitted to the secretariat of UNFCCC stating the current BAU situation in Iraq. The INC contains a projection for the year 2035 using a linear regression in Excel and the equation $Y=2806.1x+50962$, and introduces the concept of ideal future national resilience thinking to tackle climate change in Iraq, taking the new global sustainable vision in consideration.

6.5 Results

6.5.1 *Evaluating exposure of the CM to climate change by mapping past changes in air temperature and rainfall for the marshlands and in other regions in Iraq.*

a. *Exposure to temperature*

As outlined in the Methods, temperatures are predicted to increase in Baghdad in the future but it is unlikely that this increase will be homogenous across all of Iraq. Analysis of the historical temperature data indicated that the mean temperature was different between the North, West, East, Middle, and South of Iraq. The lowest mean was 19.6 °C in Rutba station in the west of the country and the highest mean was 25.3°C was in Basrah station in the south (Table 6.1). These temperatures can be categorized into three groups: i) Basrah and Nasiriyah in the south, ii) Baghdad and Khanaqin in the middle and East, and iii) Rutba and Mosul in the West and North of Iraq.

Table 6.1. Mean temperature for six different meteorological stations in Iraq (warming = mean forecast – whole record mean). *the whole record mean was calculated as the average across n years for which data were available (Nasiriyah and Basrah (in the south), and Khanaqin (in the east) had data from 1941 – 2014. Mosul (in the north) had data from 1937 – 2014, Rutba (in the west) had data from 1938 – 2013, and Baghdad (in the middle) had data from 1980 – 2014). Temperature forecasts were based on predictions from least squares linear regression. Means that do not share a letter are significantly different.

Station (n years)	Altitude of station (m)	Whole record annual mean (ºC)*	Standard Error
Baghdad (34)	34	22.8 **B**	0.1
Basrah (73)	2	25.3 **A**	0.2
Mosul (77)	223	20.2 **C**	0.1
Rutba (75)	615	19.6 **C**	0.1
Nasiriyah (73)	3	24.8 **A**	0.1
Khanaqin (73)	202	22.7 **B**	0.2

a. Exposure to rainfall

As indicated in the Methods, it is predicted that rainfall patterns will differ across Iraq in the future. Analysis of the historical rainfall data indicated that the mean rainfall was different between the North, West, East, Middle, and South of Iraq.

The largest mean value was in the north at 352 mm and the lowest was in the west at 114 mm (Table 6.2).

Table 6.2. Mean rainfall for six different meteorological stations in Iraq. *the whole record mean was calculated as the average across n years for which data were available (Nasiriyah and Basrah (in the south), Khanaqin (in the east), and Mosul (in the north) data of the four stations from 1960 – 2013. Rutba (in the west) data from 1966 – 2013, and Baghdad (in the middle) data from 1938 – 2012). Rainfall forecasts were based on linear regression.

Station (n years)	Whole record mean per annum (mm)	Standard Error
Baghdad (74)	137	0.7
Basrah (53)	138	0.7
Mosul (53)	352	1.3
Rutba (47)	114	0.7
Nasiriyah (53)	120	0.6
Khanaqin (53)	302	1.1

6.5.2 *Vulnerability of the CM to climate change and its impact on socio-economic and biodiversity receptors (birds as key species):*

a. *At the site level:*

We highlighted the existence of key factors / characteristics (Table 6.3 and Table 6.4) that can be used to determine and evaluate the vulnerability of the CM's ecosystem to climate change impacts at the site level. The current characteristics of the CM and the challenges that face the area indicated the site's vulnerability to the potential impact of climate change.

Table 6.3. Socio – Economic characteristics of the CM used to evaluate vulnerability of the site to climate change.

Characteristics	**Exists (YES / NO)**	**Details** (using data from Chapter 4; Abid *et al.*, 2007; Fazaa, Dunn and Whittingham, 2015, 2017; Nature Iraq, 2017)	**Vulnerability of the CM**
• People part of the ecosystem, human resources, and levels of wealth and income	YES	- People are part of the CM's natural system (the site can be defined as a socio – ecological system). Local people have used the habitat of the site since the Sumerian era thousands of years. - Local people of the CM (Ma'adan) migrated out the area between 1993-2003 due to desiccation of the site by the government. - The population has increased significantly after the restoration of the site in 2003 (the population across the entire CM including Chibayish City was 41,000 in 2005; 52,844 in 2015 and is predicted to be 64,100 in 2025 (Nature Iraq, 2006a). - The population of Chibayish city was 16,915 in 2006 (Nature Iraq, 2006a), and 25,000 in 2015 (Central Statistical Organisation Iraq, 2017). - The mean income of the local people was estimated to be $200-300/month between 2003	CM is vulnerable to climate change

Characteristics	Exists (YES / NO)	Details (using data from Chapter 4; Abid *et al.*, 2007; Fazaa, Dunn and Whittingham, 2015, 2017; Nature Iraq, 2017)	Vulnerability of the CM
		and 2006 (Nature Iraq, 2006a)	
Resources for livelihood	YES	- Local people of the CM are highly dependent on two main natural resources: the Euphrates River (the river is facing problem of water scarcity and increasing level of salinity (Chapter 4; Nature Iraq, 2006a) and ecosystem services that are provided by the CM.	
Ecosystem services	YES	- The CM provides many services and the local people are highly dependent on the site for several daily activities such as: grazing of water buffalo, selling of water buffalo milk, plant harvesting and trading, fishing and fish trading and feeding their water buffalo with fodder from the CM (see Chapter 4 for details). - Water buffalo are considered the most important animal for local people (Ma'adan). The animal is very sensitive to water quality and temperature. Accordingly, the local people track the buffalo across the CM and do not stay within one area. (Abid *et al.*, 2007) - The global value of the wetlands = \$30,000/ha (Sukhdev *et al.*, 2010). The total area of the CM is 30,000 ha and the current	

Characteristics	Exists (YES / NO)	Details (using data from Chapter 4; Abid *et al.*, 2007; Fazaa, Dunn and Whittingham, 2015, 2017; Nature Iraq, 2017)	Vulnerability of the CM
		protected area is 141,615 ha, therefore, in the scenario of 100% restoration and flooding the total value of the CM will be 90,000,000 USD/ha, and 4,248,450 USD/ha for the protected area. - In Chapter 4 we estimated the CM's ecosystem services to be 860,078.23 USD by valuing 40,000 ha of the total area of the CM.	
Dependence	YES	- Local people in the CM are highly dependent on the Euphrates River and the CM's ecosystem services.	
Socio – cultural	YES	- The CM is one of the main three Mesopotamian Marshlands nominated as world heritage sites in 2016 by UNESCO.	
Infrastructure, technology, and local skills	YES	- Villages inside the CM are constructed by mud and reeds, which are considered vulnerable to climate change (it is simple houses and did not provide protection from bad climate) - Skills of local people who live inside the CM are limited to hunting, fishing, grazing of water buffalos and some traditional crafts.	

Table 6.4. Ecological characteristics of the CM used to evaluate Vulnerability of the site to climate change.

Ecological characteristics	**Ecological characteristics of the CM site**	**Details (using data of the bird survey and status of *Rafetus euphraticus* (Fazaa, Dunn and Whittingham, 2015, 2017))**	**Vulnerability**
Key fauna species:	1- Euphrates soft-shelled turtle *Rafetus euphraticus* 2- Bird species	1- The maximum population size of *Rafetus euphraticus* that is likely to be sustained by the CM is 212 - 283 individuals/141,615 ha. - The CM provides breeding habitat for the globally endangered Euphrates soft – shelled turtle. - The main current water source of the CM (the Euphrates River) is facing problems of water scarcity and increasing levels of salts and heavy metals. - The 1.7 m soil embankment constructed in 2011 has made the CM the terminal site for the Euphrates' water, which could further increase levels of salinity and accumulation of heavy metals. - The soil embankment could reduce habitat connectivity by	Exist population of globally endangered species in the site make the CM defines as vulnerable to climate change

Ecological characteristics	**Ecological characteristics of the CM site**	**Details (using data of the bird survey and status of *Rafetus euphraticus*** (Fazaa, Dunn and Whittingham, 2015, 2017)**)**	**Vulnerability**
		preventing the Tigress River meeting the Euphrates. - *Rafetus euphraticus* species is highly dependent on the CM site. - Future exposure of the CM to increasing temperatures plus water scarcity could be strong stressors for the CM site and are serious threats for the highly-endangered turtle. Consequently, the CM site could be defined as a highly vulnerable site to climate change. 2- 125 bird species were recorded in the CM (14 breeding species, 11 important for conservation; with migrant and resident water birds recorded in the area). - Dependence of high numbers of bird species including important species for conservation	

Ecological characteristics	**Ecological characteristics of the CM site**	**Details (using data of the bird survey and status of *Rafetus euphraticus* (Fazaa, Dunn and Whittingham, 2015, 2017))**	**Vulnerability**
		and the globally endangered species on the CM increases the importance of the site and its priority for highly conservation work, which could increase the vulnerability of the site to potential impacts of climate change in the future.	
KBA site (Birdlife criteria)	Criterion V: “Vulnerability Criterion: Presence of Critically Endangered and Endangered species – presence of a single individual or Vulnerable species.	- Presence of the globally endangered species *Rafetus Euphraticus.* - The CM is a breeding site for 14 bird species.	
IBA site (Birdlife Criteria)	Criterion A1. Globally threatened species	Presence of 1- Basra Reed Warbler *Acrocephalus griseldis* (Summer visitor) 2- Marbled Duck (Resident) *Marmaronetta angustirostris*	

b. At the species level:

The arithmetic ranges of global environmental tolerance values (maximum temperature) for all analysed bird species were less than the calculated mean maximum temperature in the CM and the predicted maximum temperatures for 2050 and 2100 from published sources.

We assumed that the tolerance to changes in maximum temperatures by bird species we analysed will differ between species (the higher the global tolerance value, the less vulnerable the species will be to rising temperatures). Based on published forecasts, the CM site will be exposed to higher temperature (than at present) in 2050 and 2100, especially in the summer with less exposure to rainfall changes in winter. Four bird species were scored as highly vulnerable in the CM to these changes with scores of 3.5 – 4 (Black Francolin *Francolinus francolinus*, Purple Swamphen *Porphyrio porphyrio*, Iraq Babbler *Turdoides altirostris*, and Red-Wattled Lapwing *Vanellus indicus*), three species scored 3, seventeen species scored 2.5, twenty-seven species scored 2, twenty species scored 1.5, twenty-three species scored 1, and six species scored 0.5 (see Table 6.5 for more details).

Table 6.5. Vulnerability of bird species to climate change in the CM.

Scientific Name	**English Name**	**Vulnerability score**
Francolinus francolinus	Black Francolin	4
Porphyrio porphyrio	Purple Swamphen	4
Turdoides altirostris	Iraq Babbler	4
Vanellus indicus	Red-Wattled Lapwing	3.5
Botaurus stellaris	Eurasian Bittern	3
Glareola pratincola	Collared Pratincole	3
Pycnonotus leucotis	White eared Bulbul	3
Acrocephalus griseldis	Basra Reed Warbler	2.5
Alcedo atthis	Common Kingfisher	2.5
Ardea purpurea	Purple Heron	2.5

Scientific Name	**English Name**	**Vulnerability score**
Ardeola ralloides	Squacco Heron	2.5
Ceryle rudis	Pied Kingfisher	2.5
Charadrius alexandrinus	Kentish Plover	2.5
Chlidonias hybrida	Whiskered Tern	2.5
Halcyon smyrnensis	White-breasted kingfisher	2.5
Ixobrychus minutus	Little Bittern	2.5
Marmaronetta angustirostris	Marbled Duck	2.5
Nycticorax nycticorax	Black Crowned Night Heron	2.5
Passer moabiticus	Dead Sea Sparrow	2.5
Prinia gracilis	Graceful Prinia	2.5
Pterocles alchata	Pin-tailed Sandgrouse	2.5
Sternula albifrons	Little Tern	2.5
Streptopelia decaocto	Eurasian Collard Dove	2.5
Pelecanus onocrotalus	Great White Pelican	2.5
Acrocephalus arundinaceus	Great Reed Warbler	2
Anser Anser	Greylag Goose	2
Aquila nipalensis	Steppe Eagle	2
Ardea alba	Great White Egret	2
Chlidonias leucopterus	White Winged Tern	2
Ciconia ciconia	White Stork	2
Circus aeruginosus	Western Marsh Harrier	2
Egretta garzetta	Little Egret	2
Erithacus rubecula	European Robin	2
Gallinula chloropus	Common Moorhen	2

Scientific Name	**English Name**	**Vulnerability score**
Himantopus himantopus	Black-winged Stilt	2
Hirundo rustica	Barn Swallow	2
Larus genei	Slender-billed Gull	2
Merops persicus	Blue-cheeked Bee eater	2
Microcarbo pygmaeus	Pygmy Cormorant	2
Miliaria calandra	Corn Bunting	2
Passer domesticus	House Sparrow	2
Rallus aquaticus	Water Rail	2
Riparia riparia	San Marten	2
Spilopelia senegalensis	Laughing Dove	2
Sterna hirundo	Common Tern	2
Streptopelia turtur	European Turtle Dove	2
Tachybaptus ruficollis	Little Grebe	2
Threskiornis aethiopicus	African Sacred Ibis	2
Turdoides caudata	Afghan Babbler	2
Vanellus leucurus	White-tailed Lapwing	2
Vanellus spinosus	Spur- Winged Lapwing	2
Anas crecca	Eurasian Teal	1.5
Buteo rufinus	Longed-legged Buzzard	1.5
Calidris ferruginea	Curlew sandpiper	1.5
Calidris minuta	Little Stint	1.5
Calidris pugnax	Ruff	1.5
Charadrius hiaticula	Common Ringed Plover	1.5

Scientific Name	**English Name**	**Vulnerability score**
Circus pygargus	Montagu's Harrier	1.5
Clanga clanga	Greater Spotted Eagle	1.5
Emberiza schoeniclus	Reed Bunting	1.5
Gallinago gallinago	Common Snipe	1.5
Haliaeetus albicilla	White-tailed Sea Eagle	1.5
Lanius isabellinus	Isabelline Shrike	1.5
Motacilla citreola	Citrine Wagtail	1.5
Phalacrocorax carbo	Great Cormorant	1.5
Plegadis falcinellus	Glossy Ibis	1.5
Spatula querquedula	Garganey	1.5
Tringa stagnatilis	Marsh Sandpiper	1.5
Turdus philomelos	Song Thrush	1.5
Tyto alba	Common Barn Owl	1.5
Zapornia parva	Little Crake	1.5
Accipiter nisus	Eurasian Sparrowhawk	1
Acrocephalus schoenobaenus	Sedge Warbler	1
Anas acuta	Northern Pintail	1
Anthus spinoletta	Water Pipit	1
Ardea cinerea	Grey Heron	1
Aythya nyroca	Ferruginous Duck	1
Charadrius dubius	Little Ringed Plover	1
Circaetus gallicus	Short-toed Snake eagle	1
Circus macrourus	Pallid Harrier	1
Falco subbuteo	Eurasian Hobby	1
Falco tinnunculus	Common Kestrel	1

Scientific Name	English Name	Vulnerability score
Fulica atra	Common Coot	1
Galerida cristata	Crested Lark	1
Larus ridibundus	Black-headed Gull	1
Luscinia svecica	Bluethroat	1
Podiceps cristatus	Great Crested Grebe	1
Saxicola torquatus	Common Stonechat	1
Spatula clypeata	Northern Shoveler	1
Sturnus vulgaris	Common Starling	1
Tringa glareola	Wood Sandpiper	1
Tringa nebularia	Common Green Shank	1
Tringa ochropus	Green Sandpiper	1
Tringa totanus	Common Redshank	1
Anas plat	Mallard	0.5
Erythropygia galactotes	Rufous-tailed Scrub robin	0.5
Motacilla alba	White Wagtail	0.5
Oenanthe oenanthe	Northern Wheatear	0.5
Phylloscopus collybita	Common Chiffchaff	0.5
Phylloscopus trochilus	Willow Warbler	0.5
Acrocephalus scirpaceus	Eurasian Reed Warbler	NA
Actitis hypoleucos	Common Sandpiper	NA
Aegypius monachus	Cinereous Vulture	NA
Bubulcus ibis	Cattle Egret	NA
Calidris alba	Sanderling	NA
Caprimulgus europaeus	Egyptian Nightjar	NA
Elanus caeruleus	Black Winged Kite	NA

Scientific Name	English Name	Vulnerability score
Emberiza hortulana	Ortolan Bunting	NA
Gelochelidon nilotica	Gull-billed Tern	NA
Lanius collurio	Red-backed Shrike	NA
Lanius minor	Lesser Grey Shrike	NA
Larus armenicus	Armenian Gull	NA
Merops apiaster	European Bee-eater	NA
Motacilla flava	Yellow Wagtail	NA
Oenanthe hispanica	Black -eared Wheatear	NA
Oriolus oriolus	Eurasian Golden Oriole	NA
Passer hispaniolensis	Spanish Sparrow	NA
Phoenicurus phoenicurus	Common Redstart	NA
Porzana porzana	Spotted Crake	NA
Saxicola rubetra	Winchat	NA
Upupa epops	Eurasian Hoopoe	NA
Xenus cinereus	Terek Sandpiper	NA

6.5.3 *Informing policy suggestions for future national resilience planning to tackle climate change in Iraq.*

Climate change is a global phenomenon that requires urgent action at both international and national levels to increase the resilience of natural ecosystems to climate change impacts. Resilience is defined as the ability to deal with changes and relies on adaptability, transformation, and persistence. However, enhancing the adaptability of ecosystems and transforming them to resilient and sustainable systems is a long and difficult process, and needs effective implementation from the people and government. Thus, we decided to calculate the 'business as usual' scenario for CO_2 emissions in Iraq, which will help inform the national adaptation policy of Iraq to climate change and identify the best way of adapting the CM site to potential climate change impacts. We used data on Iraq's CO_2 emission that were published in the official UN site of Millennium Development Goals (UN Statistics Division, 2017) to identify Iraq's business as usual emissions from 1990-2011 and to make a prediction for 2035 using linear regression in Excel. Equivalent CO_2 emissions (metric ton) in Iraq were calculated to be 52,555.4, 68,308.9, 158,951 and 201,042.6 in 1990, 1997, 2020, and 2035 respectively (Figures 6.2 and 6.3; details provided in Appendix 6).

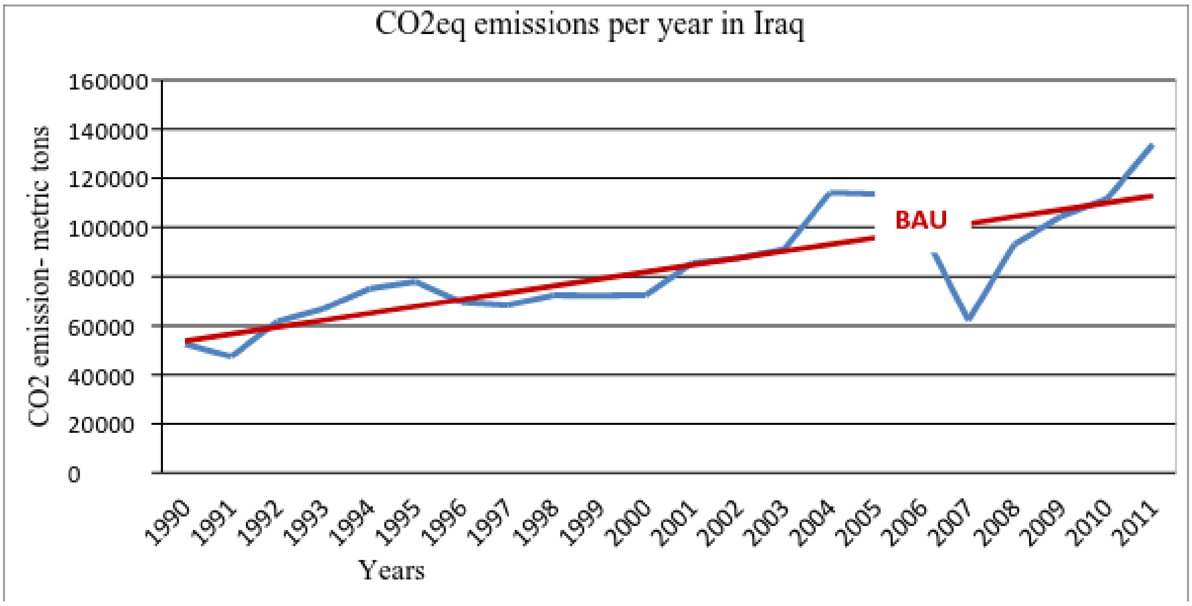

Figure: 6.2. CO_2 emission of Iraq from 1990 – 2011 using UN MDG data. The blue line shows the raw data and the red line shows the linear regression based on the raw data, which was used to predict 'business as usual' (BAU) levels of CO_2 emissions in the future.

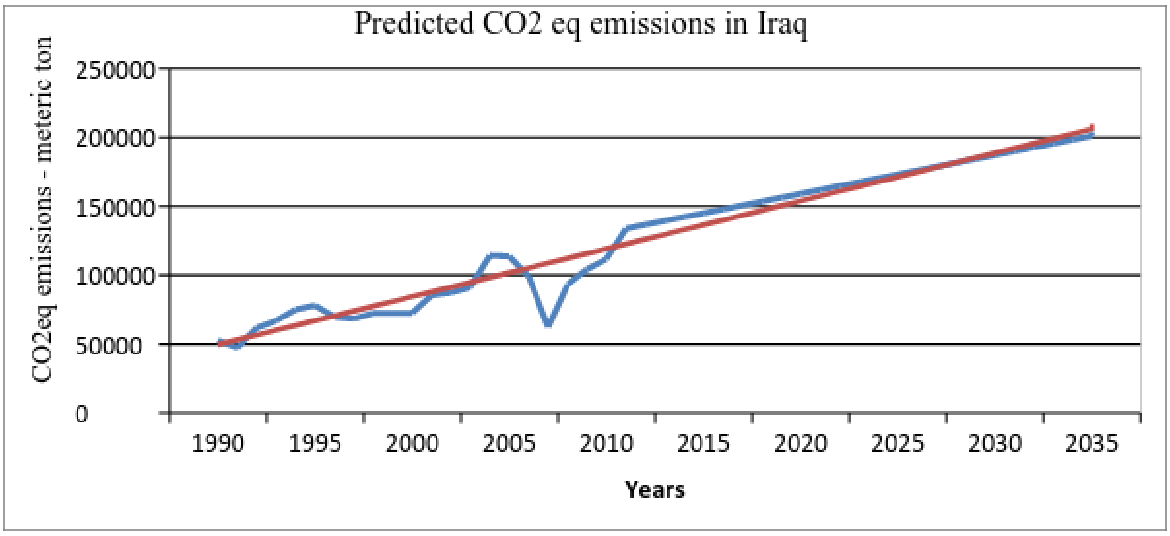

Figure: 6.3. Projection of CO_2 emissions of Iraq from 1990 – 2035 using UN MDG data. The blue line shows the raw data up until 2011 with the orange line showing the linear regression for BAU emissions.

6.6 Discussion

Anthropogenic climate change is supported by a wealth of scientific evidence and has resulted in the formation of the Intergovernmental Panel on Climate Change (Stocker, 2014). Global CO_2 emissions have increased 40% more than pre-industrial levels, hence, global mean temperatures are likely to increase by 2.6-4.8 °C at the end of this century if global business as usual (BAU) continues as it is (IPCC, 2007; Stocker, 2014). However, the impact of climate change will not be uniform for all countries with the high potential of extreme, unprecedented environmental events occurring in different areas (Stocker, 2014). Changes in global temperature, rainfall, and rising ocean levels are features of climate change. Although 90% of the domestic budget in Iraq relies on fossil fuels (Iraq Prime Minister Advisory Commission, 2012) forty years of conflict and wars, the recent economic crisis, bad security, water scarcity and environmental problems have left the country as one of the most vulnerable to climate change in the Middle East (www.iauiraq.org, 2012). Despite the poor current situation in Iraq, few studies have focused on evaluating the impacts of climate change as an additional stressor upon the country and there is no information regarding the impacts of climate change on the marshlands in southern Iraq. Previous studies have indicated changes in temperature and rainfall between the past and present in Iraq, but there is no clear projection available at the country level. Such studies have showed that the mean temperature increased by 1.5-2.5 °C in the period from 1941 to 2009 (Ministry of Health and Environment, 2016) and by +5°C in the period 1960 to 2007 (Awadh and Ahmad, 2012). The same studies indicated a reduction in annual mean rainfall from 550mm to 200mm in the North and from 250mm to 75mm in the South, which remained steady in the West for the same period. Neither of these previous studies predicted climate changes in the future. Our study suggests that the Iraqi CM is highly-exposed to climate change in terms of temperature and rain precipitation, although we caution that as the impact of climate change will not be uniform across Iraq, further more detailed site-specific predictions are also needed.

Based on our analyses, the south of Iraq is likely to be the most exposed part to climate change and will face a significant increase in mean temperature. However, the area is likely to face different circumstances in terms of rain precipitation. In this regard, the south of Iraq can be divided into two different areas: Basrah, which is located on the coastal plain is likely to face severe reduction in rainfall in 2050 and 2100, while Nasiriyah and the Marshland areas will witness an increase in mean rainfall by in 2050 and in 2100. Similarly, rainfall in the West of Iraq is likely to increase in 2050 and 2100 respectively. Given these results, the CM ecosystem site and its key species are likely to be exposed to climate change and face severe drought summers with high increases in the mean temperature, which may lead to large habitat losses. This could push the CM ecosystem past a tipping point and transform it into a novel regime with wet winters and increased rain precipitation, which may result from ecosystem feedback. The results we present could be used as a basis for future detailed studies on Iraq's exposure to climate change that could use more advanced methods and climate change scenarios.

The CM is defined as a socio-ecological system with a high dependence of local people on ecosystem services. Although, there is no universal method used to evaluate natural site and species vulnerability to climate change (Pacifici *et al.*, 2015), a specific design was adopted for this study by considering the interactions of the local with the ecosystem in the CM, and evaluating threats (mainly from climate change) via socio-economic and ecological surveys.

The results from the socio-economic data collected have clearly highlighted a critical dependence of the CM on its main source of water, which is the Euphrates River. The river is currently facing problems of water scarcity that pushed the local authority to make a soil embankment in the East side of Chibayish city on the border with Modina city in Basra province to divert the water of Euphrates to the CM as discussed in Chapter 5. The river also shows future potential exposure to changing temperatures as shown in this study. In addition, the local people's daily activities are still like their Sumerian predecessors and they have low incomes of $200-300/month (Al-Lami *et al.*, 2013), which make them highly dependent on the CM's ecosystem services. These results demonstrate the high vulnerability of the CM and the Ma'adan Arabs to the expected extreme events that could happen due to climate change. The CM could be changed to a novel regime under the scenario of climate change impact. In this case, the estimated economic lost and damage in the CM could be 90,000.00 USD for the whole area of the 300,000 ha site according to the estimation of (Sukhdev *et al.*, 2010), or could be 860,078.23 USD/40,000 ha according to estimation provided in Chapter 4.

Our results suggested a high sensitivity of the CM's water buffalo to water quality/temperature and air temperature, which shapes their movement inside the CM and creates a strong relationship between the water buffalo and Ma'adan. Consequently, the CM's local people and its water buffalo do not reside permanently in one place. The water buffalo seek fresh water with less salinity and accordingly, they move deep inside the marsh and away from the main source of water, the Euphrates River, in winter when the marsh's water is less saline (Fazaa, 2007). In summer, they withdraw towards the Euphrates when the water inside the marsh becomes saltier. Thus, we suggest the Ma'adan and their water buffalo are the most vulnerable components of the CM site to climate change and should take priority in future adaptation actions directed towards local people. Enhancing local legislative regulations that can help to allocate suitable water shares to the CM could be one of the important steps to increase the adaptability of Ma’adan and the water buffalos to climate change. Creating water buffalo farms near the Euphrates River and providing solar energy plants could increase the adaptability of the water buffalo and Ma’adan to adapt to climate change impacts and could decrease the potential for human emigration from the area, which could result in possible conflict.

The study has highlighted bird species as an important fauna in the CM with some species likely to be impacted by climate change. Resident bird species, summer visitor species, and breeding species were the most exposed and highly vulnerable vs. migratory species and winter visitor species. The method of evaluating vulnerability in bird species in the CM was designed by the authors and used for the first time for this purpose. Although we calculated the mean, minimum and maximum temperature for each species in its global range, we compared just the mean of the maximum temperature of each species with a predicted mean of maximum temperature in the CM in 2050 and 2100, because we believe that tolerance of birds to its maximum temperature range is a good indicator/factor that could be used to evaluate bird exposure to increasing temperatures. We also calculated endemism and habitat percentage of species. All examined bird species were found to tolerate the maximum predicted temperatures in the region based on the existing maximum temperatures found within their global ranges. However, the method helped to highlight differences between the responses of bird species to the predicted changes in the mean maximum temperatures in the CM and allowed us to evaluate the vulnerability of different species to future scenarios. The methods of evaluating the vulnerability of the CM to climate change that were adopted in this study could be a novel pathway that can help to improve and support current management plans for the CM, and could be adopted as a framework for other socio-ecological systems in Iraq (Iraq has 220 key biodiversity sites; Nature Iraq, 2017). However, as a caveat, we have only used simple methods to predict climate change, which could have implications for our other methodologies. For example, we gave migratory species that use the CM habitat in winter a lower vulnerability score according to our exposure findings, a decision which could be better-supported in future studies by using more advanced methods of climate change modelling and scenarios.

Resilience is defined as the ability to deal with changes and relies on adaptability, transformation, and persistence (Steffen *et al.*, 2011). According to IPCC reports (Stocker, 2014), countries needs to make a swift transformation from using fossil fuels to renewable energy and clean mechanisms to mitigate CO_2 emissions, which is considered a first and important step for adaptation under climate change circumstances. Despite the efforts spent by Iraq to meet the requirements of UNFCCC after joining the convention in 2009, its current national strategies and economy still relies heavily on oil and fossil fuel. Total CO_2eq emissions were 72.658 Gg in 1997 (Iraq baseline year), which represented 3.2 Mg/capita with a population of 19,184,543 (Ministry of Health and Environment, 2016) (data on CO_2 emissions are in Appendix 6 Table 6.7). Absence of an adequate greenhouse gases (GHGs) inventory in Iraq, particularly in the industry and electricity sectors could make calculations of the CO_2 equivalent emission for the baseline year of Iraq imprecise. Thus, improving the calculation of CO_2eq by creating a detailed GHGs inventory and considering missing data from the energy and industry sectors in future national documents (such as the second national communication of Iraq and national contributions to the climate global agreements) could provide a better projection scenario for Iraq's CO_2eq emissions that can support the country's economy under the expected population increase in 2030 and 2050. Additionally, the alternative scenario can help Iraq to suggest an ambitious contribution to CO_2 reduction (10%-15% could be reached) across the whole country under a BAU scenario and by adding CO_2 mitigation value that could gain from restoration and protecting the natural systems in Iraq, including the Mesopotamian Marshlands. Enhancing the national strategy mitigation by adopting the new scenario will not cause a significant effect on the country's future economic growth. Meeting the suggested ambitious future scenario of CO_2 reduction requires a shift towards resilience thinking from the Iraqi government in order to transfer the country to a decarbonised economy in

2030 and 2050. Implementing this scenario could demonstrate that Iraq is an active developing country in the field of climate change in the eyes of the global community and will support Iraq's international diplomatic position. A transformation to decarbonise its economy and make a suitable shift to an ideal future national resilience thinking in Iraq is one of the important steps to adapt both its people and natural ecosystems to climate change.

To conclude, the CM is an important socio-ecological site and part of the most important and large wetland in Iraq, the Mesopotamian marshlands. The site is exposed and vulnerable to climate change. However, making it resilient to climate change, enforcing sustainable use of its ecosystem services and adopting an adaptation plan for potential future climate change impacts is a difficult and long process, made especially difficult by the current bad economic and security situation in Iraq. However, to save the site and reduce the estimated loss and damage that could result from climate change is a priority and urgent actions need to be implemented by the government by embedding the site's management plan in national climate change policies that should be designed according to the UNFCCC criteria. Conducting socio-economic and ecological surveys at the same time to evaluate natural sites is a suitable pathway to evaluate the vulnerability of socio-ecological systems to climate change at both site and species levels. However, the results obtained from this pathway must be matched with the national implementation of CO_2 mitigation scenarios in order to provide a clear framework to develop national adaptation plans. We suggest this dual framework as a practical method of evaluating site vulnerability to climate change and developing national adaptation plans for socio-ecological systems in Iraq.

6.7 Acknowledgments

We thank Iraqi Ministry of Environment, Engineer Suzan Sami the Iraqi UNFCCC focal point, and Dr. Ali Kareem for providing technical advice. We thank the Iraqi Meteorological Organization and Seismology for providing national data of temperature and rainfall.

6.8 Appendix 6

Table 6.6. Appendix: Meteorological Stations in Iraq. The stations represent the North of Iraq (Mosul station), Middle of Iraq (Baghdad station), East of Iraq (Khanaqin station), West of Iraq Rutba station, and South of Iraq (Nasiriyah and Basrah stations).

Mosul station	Data from this station represents the mean of maximum and minimum temperature from 1937 – 2014 with gaps in years 1985, 87, 88, 89, 91, 93, 97, 2003, and mean of rainfall from 1960 - 2014
Baghdad	Data represents mean temperatures from 1980 – 2014 with gaps in years 2003 and 2004, and rainfall data from 1938 – 2014 with gaps in years 1939, 2003, and 2004
Khanaqin	Data represents mean temperatures from 1941 – 2014 with gaps in years 1955, 67, 68, 69, 70, 79, 84, 85, 86, 87, 88, 89, 93, 2003, and rainfall data from 1960 – 2014 with gap in years 1967, 68, 69, 70
Rutba	Temperature data from 1938 – 2014 with gaps in years 1941, 46, 47, 66, 84, 87, 88, 89, 2003, 2004, and rainfall data from 1966 – 2014 with gaps in years 1971, 72, 73, 74, 75, 76, 77, 78, 79, 80
Nasiriyah	Temperature data from 1941 – 2014 with gaps in year 2003, and rainfall data from 1960 – 2014 (CM area)
Basrah	Temperature data from 1941 – 2014 with gap in years 2003 and 2004, and rainfall data from 1960 - 2014

Table 6.7. Appendix: CO_2 emission of Iraq from MDG (1990 – 2011) and projection data from 2012-2035.

Year	CO_2 emissions
1990	52555.4
1991	47421.6
1992	61671.6
1993	66801.7
1994	75045.2
1995	77901.7
1996	69500.7
1997	68308.9
1998	72371.9
1999	72283.9
2000	72445.3
2001	85342.1
2002	87259.9
2003	91117.6
2004	114084
2005	113523
2006	98770.6
2007	62155.7
2008	93149.1
2009	104296.8
2010	111447.5
2011	133654.8

Year	CO_2 emissions
2012	136502.3
2013	139308.4
2014	142114.5
2015	144920.6
2016	147726.7
2017	150532.8
2018	153338.9
2019	156145
2020	158951.1
2021	161757.2
2022	164563.3
2023	167369.4
2024	170175.5
2025	172981.6
2026	175787.7
2027	178593.8
2028	181399.9
2029	184206
2030	187012.1
2031	189818.2
2032	192624.3
2033	195430.4
2034	198236.5
2035	201042.6
2036	203848.7

Chapter 7. General Discussion and conclusions

Ecosystems and biodiversity are currently facing large losses (Sukhdev *et al.*, 2010). Climate change is defined as a serious global threat and could lead to further loss and damage to global ecosystems and biodiversity (Pachauri *et al.*, 2014). As a result, global recommendations, commitments, and goals under the international conventions CBD and UNFCCC have been adopted to protect ecosystems and biodiversity and to reduce such loss and damage (e.g. Aichi targets and 5th IPCC report) (Stocker, 2014). Enhancing national conservation plans and methodologies by considering climate change as a major threat could play an important role in achieving these commitments. However, deciding which ecosystem and species are most exposed and vulnerable to climate change is a challenge due to a lack of universal methodology and data shortages (Pacifici *et al.*, 2015). Iraq signed the UNFCCC and CBD in 2009, some 17 years after the convention was first created in 1992 (Pachauri *et al.*, 2014). The late ratification of Iraq created a large discrepancy with the rest of the world and the parties of the UNFCCC and CBD, and a concomitant lack of national scientific publications regarding climate change. Therefore, we focused in this thesis on the Central Marsh, which is one of the most important natural sites and the first national park in Iraq, to provide results and recommendations that can fill some of the gaps in the field of climate change and its impacts on the natural systems. In addition, the thesis could be used as a case study that could be applied to other natural systems in Iraq. We aimed in this study to answer the main question: “is the Central Marsh exposed and vulnerable to climate change?”, and then we aimed to answer the following questions: should the government give priority to the protection of the Central Marsh under the circumstance of climate change? How much loss and damage will occur if the site is affected by the climate change? How we can improve, aid, and enhance the site management plan to make it less vulnerable and increase its adaptive ability? Which species are key and most vulnerable to climate change in the Central Marsh and most important for conservation? Are the local people vulnerable to climate change? To answer these questions, we decided to make a specific design for the site by dividing the area of study into three zones and three transects, and conducted two kinds of surveys: ecological and socio-economic surveys at the same time. In addition, to know the current major threats that affect the Central Marsh and to identify the key animal species in the site and to aid management plans we have put individual goals in chapters 2, 3, 4 and 5. Then we examined the major future threat, which is climate change in chapter 6 by evaluating the site' exposure to temperature and rainfall changes and evaluated vulnerability of the site and its species (birds as example). The study has provided an answer to the main question "is the Central Marsh exposed and vulnerable to climate change?". The answer helps to direct Iraq's national efforts about how to evaluate impact of climate change on the natural ecosystems in Iraq.

Iraq is defined as the most vulnerable country in the Middle East to climate change (www.iauiraq.org, 2012). Previous studies have indicated changes of temperature and rain fall between past and present while there is no clear projection available on the country level. The mean temperature has increased by 1.5-2.5 °C in the period between 1941 - 2009 (Ministry of Health and Environment, 2016) and by 5°C in the period 1960 to 2007 (Awadh and Ahmad, 2012). The same studies indicated a reduction in annual mean rainfall from 550 to 200mm in the North and from 250 to 75mm in the South and remained steady in the West for the same period.

Our study suggests that Iraq is a highly exposure country to climate change in terms of temperature and rain precipitation, and the impact of climate change is not uniform. The South of Iraq is likely to be the most exposed part and will face significant increases in mean temperature. However, the area is likely to face different circumstances in terms of rain precipitation. In this regards, the South of Iraq can be divided into two different areas: Basrah, which is located on the costal part is likely to face a severe reduction in rainfall in 2050 and 2100, while Nasiriyah and the Marshland areas will witness an increase in the mean rainfall in 2050 and in 2100. Similarly, rainfall in the West of Iraq is likely to increase in 2050 and 2100 respectively.

Given this result, the Central Marsh ecosystem site and its key species are likely to face severe drought summers with a high increase in the mean temperature, which may lead to extensive habitat loss, threatening to pass the tipping point and transform to a novel regime. Similarly, wet winters with increasing rain precipitation, may result in marshlands' ecosystem feedback. Besides the exposure our results define the CM as a highly vulnerable site to climate change, which is a wake-up call for urgent adaptation actions that can improve the capability of the Marsh Arabs (Ma'adan) to adapt against the potential expected severe changes in climate and to decrease the vulnerability of the CM site. Given the different future circumstances in the CM, breeding and summering species (14 breeding bird species and Euphrates Soft-shelled turtle *Rafetus Euphraticus*) are likely to be highly vulnerable vs. migratory and wintering species. Moreover, our socio-economic survey indicated the high sensitivity of the CM's water buffalo to water quality and temperature and air temperature, which limits its movement inside the CM and shapes the strong relationship between the water buffalo and Ma'adan. Local people and water buffalo are not found permanently in one place within the CM, because the buffalo are highly limited by water quality. They seek fresh water with less salinity, and accordingly, they move deep inside the marsh and away from the main source of water, the Euphrates River in winter when the marsh's water is less saline and they withdraw towards the Euphrates in summer when the water inside the marsh is saltier. Thus, we suggest the Ma'adan and their water buffalo are the most vulnerable components of the CM's site to climate change and should take priority in future local adaptation actions. In addition, the loss and damage of the CM ecosystem services that could result due to climate change was valued at 860,078.23 USD USD/ 6 months. The CM is one of 220 KBA sites in Iraq, and future assessments of exposure and vulnerability of natural ecosystems to climate change needs to focus on other KBA sites in Iraq in order to assess conservation priorities in terms of exposure and vulnerability.

Resilience is defined as an ability to deal with changes and relies on adaptability, transformation, and persistence (Steffen *et al.*, 2011). According to the IPCC reports countries need to make swift transformations from using fossil fuels to renewable energy and clean mechanisms to decrease CO_2 mitigate CO_2

emissions, which is considered a first and important step for adaptation under climate change circumstances. Despite the huge efforts spent by Iraq to meet the requirements of UNFCCC after joining the convention in 2009 its current national strategies and economy still relies on oil and fossil fuel. Total emission of CO_2eq was 72.658 Gg in 1997 (Iraq baseline year), which represent 3.2 Mg/capita and the national population was 19,184,543 (Ministry of Health and Environment, 2016). Industry sector activities in Iraq were very low in the 90s due to an international embargo (e.g. contribution of CO_2 emissions from Iraq's industry sector were 2% in 1990 and 5% in 1997 (Iraq Prime Minister Advisory Commission, 2012). Electricity in Iraq has never reached maximum production (i.e. providing electricity 24h/day) since 1990 e.g. current total production of electricity is 11,000 MW, while the country's actual need is 23,000 MW apart from the Kurdistan region, net kWh per capita in Iraq in 2013 and 2014 was nearly 1,375 KW.h/year, compared to 8,000 KW.h/year in neighbouring countries (Iraq Prime Minister Advisory Commission, 2012). Thus, our study suggests recalculating the emissions of CO_2eq in the baseline year to consider an estimation for the missing industry emissions and make the total estimation suitable to provide at least 24h/day electricity for 19,184,543 people.

Iraq's right of development and prosperity faces climate change impacts on the Earth and the urgent transformation (decarbonised economies) that has been adopted by UNFCCC parties. However, due to Iraq's unique circumstances on economic, security and environmental levels we suggest doubling the total CO_2eq emissions of the baseline year in 1997 (or using data of 2020 as baseline for Iraq) and to make projections for the country's BAU scenario to reach its peak in 2035 and then make a reduction of 10-15% of the total BAU amount by investing in renewable energy and clean mechanisms (Figure 7.1). A gradual transformation to decarbonise the economy and make a suitable shift to ideal future national resilience thinking (policies) in Iraq is one of the important steps in adaptation of its people and natural ecosystem to climate change.

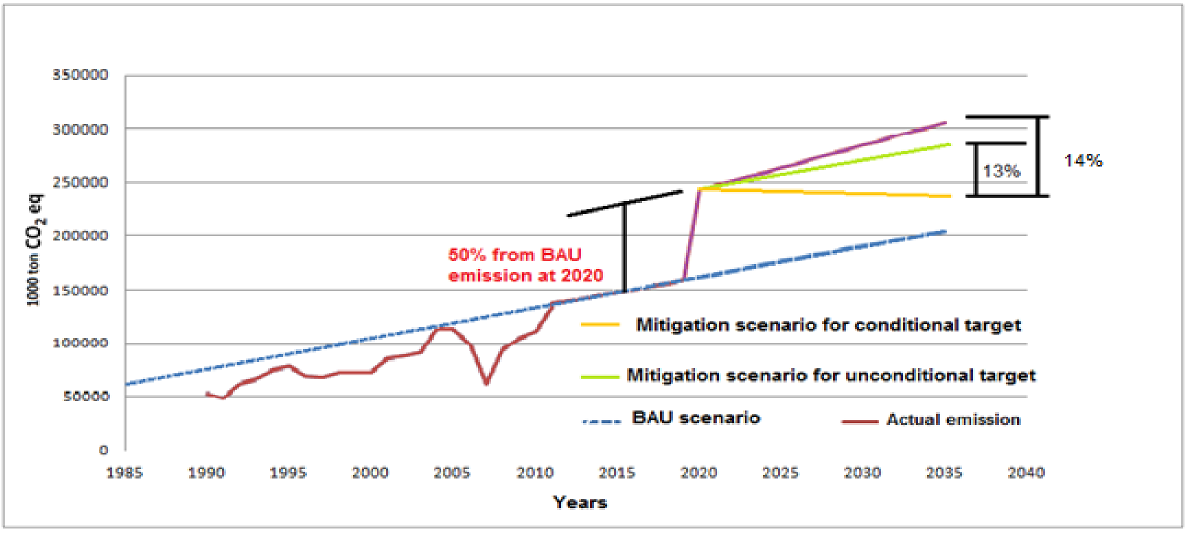

Figure 7.1. BAU and mitigation scenarios for total GHGs in Iraq (1990-2035).

7.1 Conclusions

- The Central Marsh (CM) is an important site to the local people and water buffalos (the current population of Chibayish City is 100,000 and 17,000 head of water buffalos exist around the border of the CM in Thi-Qar province.

- Local people (Ma'adan) and their water buffalos are the most vulnerable component of the Central Marsh to climate change; houses of the people are very simple and are constructed using mud, which cannot provide suitable protection from the external weather conditions; life and movement of water buffalos could be limited by temperature and water quality (water buffalo seek fresh and good water quality). Both people and water buffalos are highly dependent on water of Euphrates River, while the river currently face challenges of water scarcity, salinity, and increasing levels of pollution. Thus, under climate change circumstances people and their water buffalo could be displaced or migrate to another area and that could add more pressures on the adjacent provinces especially those located north of the Central Marsh.

- Loss and damage of the Central Marsh's ecosystem services could be 860,078.23 USD/ 6 month under severe climate change impacts scenarios.

- Salinity and pollution could be increased under climate change circumstances and that could drive the site to past the tipping point and transfer it to a novel regime.
- Keeping water level of Euphrates River at 1.29m as a minimum in the summer can support the same current situation of wildlife.
- Management plans of the CM site can be enhanced by adding details of the peoples' economic activities and more details on wildlife and assemblages and distributions of species inside the site.
- Heavy metals are currently accumulating inside the marsh and that could affect the locals through the food chain (heavy metals could be accumulated in muscles of fish and milk of water buffalos).
-The habitat of the Central Marsh provides services for 125 bird species, 11 of them are important for conservation and 14 breed in the site. Endemic, breeding, and summer visitor bird species are more vulnerable to climate change in the Central Marsh.
- The habitat of the Central Marsh site provides services for 212-283 individuals of the globally endangered soft-shelled turtle *Rafetus euphraticus*. Under severe climate change circumstances this species could disappear from the site.
- The soil embankment on the Euphrates River could act as a barrier that prevents turtles from using both habitats of the Tigress and Euphrates Rivers.
- Zone 2 of the Central Marsh is a hot spot for breeding turtles and bird species, and this zone could be considered as the core zone for conservation. In addition, transects one and two have the most economic activities, and birds and turtle assemblages.
- Future economic projects should be undertaken in zone one, as it will act as a buffer zone that will decrease pressures on zones two and three which could be left as wild areas.
- In the scenario of enhanced water availability in both Tigress and Euphrates Rivers the core zone of the site could be expanded to include zone 3. The best scenario would be similar to the historical situation where zone 3 is provided by water from the Tigress.
- Identifying accurately the current problems and challenges could reduce the site's vulnerability and increases its adaptive capacity to climate change.

- National responses to the commitments and requirements of the international conventions such as CBD and UNFCCC are very important steps to enhance and create robust country policies that support adaptation, resilience, and sustainable development of natural systems in Iraq.

- Adopting national policies of CO_2 mitigation and controlling population growth are the most important steps for national adaptation and increasing resilience in the country.

- It is crucial for Iraq to recalculate greenhouse gases (GHGs) and CO_2 emissions by adopting an adequate GHGs national inventory. This process can be started in 2020 and would consider that year as the baseline year instead of 1997.

- Iraq should increase its oil production to hit the peak in 2035 and then offer 10-15% of its total business as usual as investment in the field of renewable energy and clean mechanisms. The suggested process corresponded with the global agreement of the UNFCCC parties that was adopted in Paris at the end of 2015 and enforced in April 2016 where all countries were asked to submit their Intended Nationally Determined Contributions (INDCs) as post 2020 reduction polices. This suggestion could play dual roles by supporting Iraq's economy and compensate for the wasted fortune that happened in the past and support Iraq's diplomatic position as a party of the UNFCCC by adopting such an ambitious mitigation policy.

- Conducting both ecology and socio-economic surveys together, and identifying the unique problems of natural sites as we did in our study could be considered as an ideal methodology to evaluate vulnerability of ecosystems to climate change in Iraq.

- Repeating our study in the Central Marsh and other ecosystems by randomising the surveys and adding more economic activities of the local people could provide more precise and detailed information about ecosystem services of the site, and vulnerability to climate change.

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