SOCIAL-ECOLOGICAL ASSESSMENT FRAMEWORK FOR THE RESTORATION OF THE IRAQI MESOPOTAMIAN MARSHLANDS

By

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B.Sc. (Hons), University of Baghdad, 1995

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ENVIRONMENT AND MANAGEMENT

We accept this thesis as conforming
to the required standard

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Abstract

Efforts to restore the Mesopotamian Marshlands, the largest wetlands ecosystem in the Middle East, have been underway since 2003. However, they have lacked an integrated approach that recognizes the marshes as a complex social-ecological system. This study builds a social-ecological assessment framework to restore the marshes using a resilience thinking approach. This work describes the system and identifies specified resilience as a part of an integrated management framework. Key controlling variables, such as salinity, across scales and domains, are identified. Results suggest that the kind of system variability that has been introduced with respect to salinity levels (measured between 2010 and 2014) provides early warning that a critical threshold may be surpassed in the Mesopotamian Marshes. Managers have to be aware that irreversible change might occur if the threshold is exceeded. An integrated social-ecological assessment approach is proffered as a means to more sustainable system management.
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Chapter I: Introduction

The Mesopotamian Marshlands as a Social-Ecological System (SES) Overview

The Mesopotamian Marshlands in the southern part of Iraq (20,000 km$^2$ of permanent and seasonal marshes) are considered the crown jewel of the Middle East and are often referred to as the “Garden of Eden” (United Nations Integrated Water Task Force for Iraq, 2011; Adriansen, 2004; UNESCO, 2003; Al-Ansari & Knutsson, 2011). The Mesopotamian Marshlands comprise three separate but adjacent permanent marshes; Al Hammar, Central and Al Hawizeh marshes, and enormous seasonal marshes that form during springtime flooding (Alwash, 2013; Garstecki & Amr, 2011) (see Figure 1).

Figure 1. Southern Iraq marshes. Adapted from “University of Victoria, Institute for Dispute Resolution, Iraq Maps,” by K. Holmes, 2010.
The landscape and abundance of resources sustain a rich diversity of water-dependant wildlife in an area surrounded by deserts (Alwash, 2013; Partow, 2001). The marshlands provide natural habitat for many important bird species and freshwater fish (United Nations Integrated Water Task Force for Iraq, 2011). In addition to their historical and heritage value, the Marshes have served as a natural filter for the Tigris and Euphrates Rivers, preventing pollutants from degrading the Gulf coast (United Nations Integrated Water Task Force for Iraq, 2011). The Marshlands deliver a wide range of ecological goods and services such as food, clean water and climate control (Hussain & Grabe, 2009).

For more than 5,000 years, the Iraqi marshlands have been the home of Marsh Arabs also known as the (Ma’dan); Madan means "dweller in the plains (‘adan)" that have roots descended from ancient Sumerian and Babylonian civilizations (UNESCO, 2003). The Ma’dan has depended on the abundance of marsh resources for their survival (Alwash, 2013). Higher aquatic macrophytes, such as reeds, are important building materials for Ma’dan’s homes (Ochsenschlager, 2004). As recently as the 1990s, they were still building their homes from the marsh reeds on synthetic islands (UNESCO, 2003). In addition to reed homes, the Ma’dan has used reeds for weaving different household objects, including reed mats, baskets, and brooms (Ochsenschlager, 2004; Evans, 2003). The Ma’dan’s economy is completely built upon the aquatic environment, including fishing, rice cultivation, buffalo breeding, and reed weaving (UNESCO, 2003).

The primary water sources for this ecosystem are the Tigris and Euphrates Rivers (Al-Ansari & Knutsson, 2011) and some seasonal discharge from Iranian tributaries, precipitation, and ground water (AlMaarofi, Douabul, & Al-Saad, 2012). The Tigris and Euphrates originate from
Taurus-Zagros Mountains range in Turkey, Iraq, and Iran (UN-ESCWA and BGR, 2013) (see Figure 2).

The two streams flow from the headwaters to the Shatt Al-Arab; "Stream of the Arabs", that discharges into the Arabian Gulf (UN-ESCWA and BGR, 2013). The steep gradient of these streams, particularly in Iraq, creates large downstream movement of sediments leading to elevated stream beds and eventual flooding. The slow velocity downstream encourages the Tigris and Euphrates rivers to split away to form an inner delta; the Mesopotamian Marshlands. Ultimately, the two rivers join in the city of Qurna, a part of Basra province in southern Iraq to form Shatt al Arab River (Alwash, 2013) (see Figure 1).
Until the 1970s, the Mesopotamian Marshlands covered an area of up to 20,000 km² (Richardson & Hussain, 2006). The total area of interconnected marshes and lagoons was reduced to approximately 9,000 km² during dry seasons (Adriansen, 2004; UNESCO, 2003). In the 1990s, the government drained the marshlands ecosystem leading to the loss of the main marsh units; Al Hammar and the Central marsh, leaving only a part of Al Hawizeh marshes (Water Task Force for Iraq, 2011; Alwash, 2013) (see Figure 3).

*Figure 3*. The destruction of the Mesopotamian Marshlands during the period of 1970-2010. Adapted from “University of Victoria, Institute for Dispute Resolution, Iraq Maps,” by K. Holmes, 2010.
In addition to these local changes to the ecosystem, there are more than 30 dams upstream in Syria, Turkey, Iran and even Iraq (see Figure 4).

![Dams in the Tigris Euphrates River basin](image)

*Figure 4. Dams existing, planned, and under construction in the Tigris Euphrates River basin in 2009. Adapted from “University of Victoria, Institute for Dispute Resolution, Iraq Maps,” by K. Holmes, 2010.*

In addition, proposed projects will dramatically reduce the water flow and the seasonal floods that sustained the marshes (Canada-Iraq Marsh Initiative, 2010). The cumulative effects of international and national actions, such as the massive engineering drainage works, have resulted in 90% desiccation of the Mesopotamian Marshlands and a substantial destruction of the entire social-ecological system (SES) (Partow, 2001). Despite the destruction and drought that have occurred in the marshlands area, they still can be properly restored if coordination and cooperation between all regional participants can be achieved (Alwash, 2013). Successful restoration of such a complex ecosystem requires a mix of diverse specialties and disciplines to facilitate the formation of an integrated framework, taking into account the scale of the entire ecosystem (Mitsch, 2013). A trans-disciplinary management approach that combines the experience of
biologists, engineers, politicians, economists, and more importantly the indigenous people, is required to sustainably restore the marshes (Al-Ansari & Knutsson, 2011). Any restoration efforts controlled by scientists alone will ultimately fail because of the need to consider information and approaches from other disciplines like engineering and economics (Mitsch, 2013). Likewise, if the latter control the management practices, they will focus on their own perspectives, neglecting the science point of view (Mitsch, 2013). Building a social-ecological resilience assessment framework for the management and the restoration of SES using resilience thinking approach will help to define the most significant issues and challenges facing the system on hands (Resilience Alliance, 2007). A resilience approach to natural resource management acknowledges the uncertainties in the system (Walker et al., 2002). It also focuses on the dynamics and development of this SES in a changing world (Folke, et al., 2010).

This study elaborates on the environmental domain that have mutual relations with social behaviour and economical status (Walker & Salt, 2012). Defining the environmental controlling variables and their thresholds in the system such as water salinity, biodiversity, water flow, and water depth, and then linking them with the social and economic context helps to clearly understand the entire, system (Groffman et al., 2006) and assists to recognize when the system might shift into a new regime (Walker & Meyers, 2004). Human impacts can change the system properties and shift that system into a new irreversible state if the impacts exceed the critical thresholds (Suding & Hobbs, 2009; Groffman et al., 2006; and Walker et al., 2004). Scientific research indicates that defining such variables is essential in conservation and restoration work (Suding & Hobbs, 2009).

The purpose of this research is three-fold. First, this study aims to take an alternative approach to identify the gaps in ecological management approaches for the Iraqi marshlands
ecosystem. Second, this study answers the need to provide an assessment framework and management tool that addresses where to intervene in the system effectively to make it more resilient. Finally, it aims to present a framework that helps to address the restoration issues in the marshlands based on a trans-disciplinary research design. Although this assessment is not exhaustive, it identifies some controlling variables that help authorities, policy makers, and managers in Iraq determine where to intervene and make decisions to get sustainable change. Restoration of the 20,000 km$^2$ as a holistic ecosystem is ecologically, socially, and economically significant to the catchment area in general, and to Iraq in particular. Taking into account the marshes’ restoration using resilience thinking approach is essential for modern Iraq development because, to date, the efforts that have been done at various times and governmental scales lacked the coordination and harmonization in their framework. Building an integrated framework is a fundamental approach to wisely manage a complex socio-ecological system like the Mesopotamian Marshlands, in a chaotic and constantly changing world.

**Resilience Management in Social-Ecological Systems**

The complexity of SESs is the main obstacle that hinders natural resource managers from achieving long-term, efficient and sustainable decisions (Walker et al., 2002). Traditional management approaches, such as decision analysis, are often based on the concept that the outcome from the system is linear and predictable (Walker et al., 2002). To maintain long-term sustainability, an integrated approach that acknowledges the complexity, uncertainty, and functionality of the concerned SES, is required. Resilience analysis and management is an alternative approach that is based on maintaining the capacity of the SES to keep or rebuild the system’s identity and functionality against different kinds of disturbances (Nemec et al., 2013). This approach is a practical path to identify the resilience properties of each complex SES
(Walker et al., 2004). It consists of multiple steps that build upon a detailed history or previous case studies (Berkes & Folke, 1998) such as in our case study of the Mesopotamian Marshes in southern Iraq. Wars and hydro-engineering have left their indigenous people (Ma’adan) displaced inside Iraq and in neighbouring countries (Partow, 2001). Resilience analysis and management is a tool that will assist this SES to recover in the face of impending social-ecological collapse (Dempster, 2007). Although identifying the controlling variables and their thresholds in the system is only one step from the four-step practical approach suggested by Walker and Salt (2012), it is tremendously helpful to show, in numbers, where and when to intervene in the system. Generally natural resource managers become aware of the importance of thresholds once they have been crossed and ecosystem’s goods and services irreversibly disappeared, which is too late (Resilience Alliance, 2010).

The Essence of Resilience Thinking

The essence of resilience in different SES’s is to understand the feedbacks that keep the system self organizing within the limits of the system’s threshold values and, ultimately, maintaining its identity (http://www.stockholmresilience.org/21/research/what-is-resilience.html). Putting resilience into practice is challenging and depends on how well the system has been understood previously. Addressing system complexity means understanding the most essential things that we need to know about the system to make it more sustainable (Walker & Salt, 2012). Resilience is the dynamic property of SES’s and it requires an adaptive management approach to deal with it (Garmestani & Benson, 2013). Once resilience science is applied, it needs continuous re-examination and refinement in an adaptive way that matches the constantly changing world (Walker et al., 2004). From the ecological science point of view
“Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds” (Stockholm Resilience Centre, 2007).

For the purposes of the current research, the following are the key elements of resilience that must be considered:

- **Systems are self-organizing**: Generally, in complex systems, when change happens to a part of the system the system responds to cope with that change. However, systems have limits to their ability to maintain a dynamic equilibrium. For instance, when natural resource managers control part of the system they get predicted results but sometimes the system surprises them with its unpredicted response because it couldn’t handle that type of change. When the system doesn’t have the ability to absorb the disturbances, it loses its identity by passing its resilient thresholds.

- **Thresholds**: Thresholds are the limits of system’s self-organization characteristics. If any system crosses those limit points, it loses its identity and transforms into new one. Therefore, identifying them is a crucial step to build a resilience assessment framework. Although thresholds are not easily identified, we have to recognize them and estimate. For instance, in social domain, thresholds are about market demands, people’s values, fashion preferences, and voting intentions which are out of the scope of this research. An ecological threshold, such as salinity, is what we are looking for in this study. Crossing it, most likely, takes the Mesopotamian Marshes into different type of ecosystem; into new regime.

- **Non-linearity**: Dynamic systems are nonlinear systems which mean that a small change in a specific scale can cause a huge effect on the behavior of the system in another scale. Systems thinking involve a shift from linear to nonlinear thinking in order to
acknowledge the system’s identity. Relationships between systems components, such as linkages, cycles, feedback loops, are examples of nonlinear relationships in the system. Complex systems, such as the Mesopotamian Marshes SES, exist in alternate stable states. At any particular time, each state constitutes multiple components; environmental, social, and economical controlling variables that play in harmony with each other creating the required stability in a specific system’s configuration. Once those components of the system change, the system identity changes into alternate desirable or undesirable regimes. Alternate regimes are separated by thresholds. Once the threshold is passed in one regime it might lead to a big shift in the system configuration and eventually changes in system’s function and structure (Resilience Alliance, 2010).

- Specified Resilience: Before defining a threshold, we have to identify the controlling variables. For example, the nutrient level in a coral reef ecosystem is a controlling variable. After a good monitoring program, scientists have identified that the threshold in this system is at the point when nutrient level above it will support the growth of algae which in it turn will overcome the coral polyps’ growth. Assessing the specified resilience is a tool to present the possible thresholds in all scales (upper, focal, and lower scales) and domains (ecological, social, and economic domains) for the system on hands. Monitoring the change of controlling variable over time is a challenging task (Kinzig et al., 2006). More importantly, because of non-linear dynamics, the system can exist in alternate stable states that makes this task more challenging (Resilience alliance, 2002).

- System Disturbances: There are three main types of shocks that the system might face during the course of its existence:
- Characteristic disturbances: characteristic disturbances are known and expected from the system. Therefore, the system usually has sufficient experience dealing with them by continuously developing specific mechanism for that, for instance, annual flooding in many tropical areas. As long as the system has the ability to absorb those disturbances, it is resilient. Any change or elimination of this type of disturbance in one social-temporal scale may lead to undesirable consequences in the long term.

- Large infrequent disturbances: In comparison with characteristic disturbances, large infrequent disturbances are rare in occurrence. Systems rarely evolve any defense mechanism for them. Therefore, they might push the system into undesirable end or into different regimes (e.g., Hurricane Katrina).

- Unknown disturbances: They are the shocks that hit the system and the system doesn’t predict, anticipate, or prepare for them (e.g., terrorist attacks).
Chapter II: Research Approach and Methodology

I employed an explanatory research design structure. I chose the Mesopotamian Marshlands ecosystem as a case study to apply the resilience thinking approach for better management practices in Iraq. A mixed methods approach combining both qualitative and quantitative data collection was used in this study. This is a structured approach to applying resilience concepts to the Iraqi marshlands situation rooted in the emerging theory of resilience thinking. Although the approach is interdisciplinary, I placed particular emphasis on the ecological science elements to fulfill the requirements necessary for the M.Sc.

Data Gathering

My data are divided into two kinds; primary data and secondary data.

- Primary data are data were based on semi-structured interviews and informal conversation with representative stakeholders.
- Secondary data involved obtaining public domain datasets (e.g. Google maps and MODIS Satellite imagery dataset), as well as analyses of published grey and peer-reviewed literatures and archival materials including government and international organization reports (e.g. United Nations Environment Program (UNEP), Nature Iraq foundation, and the Ministry of Water Resources/Iraq reports).

The sample

For primary data, key informants included: Dr. Ali Douabul, Department of Marine Environmental Chemistry, Marine Science Center, University of Basra, Iraq; Dr. Azzam Alwash, the founder of Nature Iraq foundation; Dr. Suzanne Alwash, the author of “Eden Again: Hope in the Marshes of Iraq” book, Eng. Jassim Al-Asadi; local government manager; Ahmed Saleh
Alhasnawi, previous civil society leader, activist, and indigenous people; Ammar Zakri, Economy, Recovery and Development Manager at International Rescue Committee, Iraq. The selection of the stakeholders to interview was based on my resilience assessment and my expertise, as an Iraqi person, regarding which individuals have the information I need to know about the marshes issue. I used a ‘snowball’ method to identify other key informants to be included in this purposive sample. The security situation and internet communications in Iraq during study time limited the pool of key informants available to me.

For secondary data, the sample was publically available data, reports and peer-reviewed publications relevant to the social-ecological system of the marshlands, particularly ecological data such as water-related data and hydrological data; the controlling variables I am addressing in this study.

Analysis

Following the approach of a structured resilience assessment, my analysis included quantitative analysis (statistics, graphs) related to the salinity level in the marshlands and how this is influenced by the social and economic parts (i.e., key social ecological linkages and system feedbacks). The qualitative analysis helped to validate and broaden the findings in terms of important socio-ecological interactions and linkages. In the practical sense, defining the controlling variables, such as salinity, biodiversity, water depth, water flow, pH, and hydro connectivity, and working toward find their thresholds points, are powerful points to trace the system’s proximity to these thresholds or, maybe, to a regime shift (Cumming, 2011). Defining the controlling variables helps individuals and decision makers who have the authority to take action toward maintaining or restoring the resilience of this complex SES (Meadows, 2008; Walker et al.,
2002). “Lucidchart” was used as Web-based diagramming software for the current planned analysis because this tool allows research informants to collaborate in real time to create diagrams and flowcharts.

The Resilience Assessment Framework

The Resilience Assessment framework consisted of three main steps.

- Defining and describing the system on hands in terms of
- Scales (system’s boundaries)
- People and governance
- The resilience of what?
- Disturbances to the system
- Drivers and trends
- Assessing the system’s resilience
- Assessing Specified Resilience by defining
- Known Thresholds
- Thresholds of Potential Concern
- Developing Conceptual Models
- Analytical Models
- Assessing General Resilience
- Transformability
- Managing the system’s resilience

This work focuses primarily on the first two steps.
**Defining and describing the marshlands.** It is difficult to fully describe any SES. Changing conditions make this an iterative process (Walker & Salt, 2012). To facilitate this task, practitioners in resilience assessment suggest dividing the process into five main steps that are overlap and inform each other (Resilience Alliance, 2007). Although it is challenging, occasionally involving local stakeholders, knowledgeable peoples, and individuals who have legitimate sake in this process strengthens the assessment and adds legitimacy to its implementation (Schultz, et al 2007). Besides, describing the system is crucial to identify the big issue the system is currently facing and eventually helps to build a powerful resilience assessment framework. It can only be achieved by engaging individuals and/or groups who have knowledge and experience about the system. Defining the big issue starts with describing the system components and the probable connections that link those parts altogether as one whole (Walker & Salt, 2012).

**Scale (System boundaries).** It is important to define the spatial-temporal scales when dealing with complex SES's (Cumming, 2011; Perry, 1995). Considering the geophysical dimension is essential in defining the scales. Each complex system consists of many subsystems that are nested within each other to form another ecosystem within the boundaries of the original ecosystem (Reynolds & Holwell, 2010). Resilience-based frameworks acknowledge and attempt to understand the cross-scalar interactions through feedback relationships (Cumming, 2011). Scales above and below the focal scale influence its state and dynamics (Walker *et al*., 2004). The Mesopotamian Marshlands ecosystem, is a self-organising complex system that works across different scales (Perry, 1995; Walker & Salt, 2012). Doing research at any scale is considered limited if it doesn’t recognize the social domain contribution to that research work (Newing, 2011). The social scale is one of natural resource managers’ weakness points, particularly when they mismatch between the social scale and the geophysical scale. As a result, people should be
included in the decision making process to overcome any inappropriate natural resources management practices (Maarleveld & Dangbgon, 1999).

*People and governance.* In this step of describing the system, it is important to define what government level controls and operates at the scale of interest (Walker & Salt, 2012). This section identifies the governance structure, people’s property and access rights, and who controls and operates the Mesopotamian Marshlands resources. Similar to the first step in describing the system, key stakeholders should be engaged from the beginning as they play a big role in drawing the main outlines of resilience assessment framework (Walker & Salt, 2012). Defining what government level controls and operates the scale the scale of interest is helpful to define the scale itself (Walker & Salt, 2012).

*The resilience of what?* This section of assessing resilience concentrates on what marshes consist of, in terms of biophysical components (vegetation types, wildlife, crops, and water bodies), social components (indigenous people culture and values), and economical components (financial viability, infrastructures, and land use). And, how those components are influenced by upper and lower scales. This step explains what components of the system need to be resilient. What are the primary social and ecological issues? To approach these questions, an ecosystem goods and services overview will show system’s components that have direct and indirect benefits to people such as crops, fish, water, fresh air, pollination, flood control, and biodiversity (Walker & Salt, 2012). Table 1 prepared by the United Nations Integrated Water Task Force for Iraq in 2011, demonstrates four main types of goods and services provided by the Iraqi marshlands. Reviewing the literature and the detailed information presented in Table 1 helped me to produce a conceptual model of the system and a potential Threshold Matrix (see Figure 5).
Table 1

*Ecosystem services provided by or derived from the Iraqi Marshlands*

<table>
<thead>
<tr>
<th>Provisioning services - the goods of products obtained from Marshlands’ ecosystem</th>
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<tbody>
<tr>
<td><strong>Food</strong></td>
<td><strong>Crops</strong></td>
</tr>
<tr>
<td></td>
<td>Paddy rice, great millet, dates, vegetables and fruits</td>
</tr>
<tr>
<td>Livestock</td>
<td>Asian water buffalo, cattle, sheep, water-buffalo milk and yogurt</td>
</tr>
<tr>
<td>Capture fisheries</td>
<td>Shrimp, yellowfin sea bream, khishni</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Cyprinids, grass carp, shellfish</td>
</tr>
<tr>
<td>Wild foods</td>
<td>Wild boar, waterfowl (coot, teal), desert monitor</td>
</tr>
<tr>
<td>Freshwater</td>
<td>Freshwater for drinking, cleaning, cooling, and transportation (canoeing and boating)</td>
</tr>
<tr>
<td>Fiber and fuel</td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td>Reeds for housing and mats; date palm wood</td>
</tr>
<tr>
<td></td>
<td>Fuel</td>
</tr>
<tr>
<td></td>
<td>Reeds, crude oil, cattle dung</td>
</tr>
<tr>
<td>Biochemical</td>
<td></td>
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<tr>
<td></td>
<td>Potential use of Marsh flora extracts, native herbs for pharmaceuticals and pest control</td>
</tr>
<tr>
<td>Genetic materials</td>
<td></td>
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<tr>
<td></td>
<td>Resistance and breeding of native plant and animal species</td>
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</tbody>
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<tr>
<th>Regulating services – the benefits obtained from the Marshland ecosystem’s control of natural processes</th>
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</tr>
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<tbody>
<tr>
<td>Climate regulation</td>
<td>Moderation of the national rainfall patterns and control desertification and dust storms</td>
</tr>
<tr>
<td>Water regulation</td>
<td>Hydrological flows</td>
</tr>
<tr>
<td></td>
<td>Storage and retention of water flowing from Euphrates-Tigris system upstream and tidal flow downstream; Permeable clay and silt facilitates recharge of the Recent</td>
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### Social-Ecological Assessment

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Water purification and waste treatment</strong></td>
<td>Alluvium aquifer, removal of harmful pollutants from water by trapping metals and organic materials; soil microbes degrade organic waste rendering it less harmful.</td>
</tr>
<tr>
<td><strong>Erosion regulation</strong></td>
<td>Reeds, grasses and estuarine vegetation retain soils and sediments.</td>
</tr>
<tr>
<td><strong>Natural hazard regulation</strong></td>
<td>Marsh areas naturally absorb seasonal floods and tidal surges; moderation of drought at a local scale.</td>
</tr>
<tr>
<td><strong>Pollination</strong></td>
<td>Habitat for bees and birds, the key pollinators of economically important crops.</td>
</tr>
</tbody>
</table>

### Cultural services – the nonmaterial benefits that Iraqis obtain from Marshlands ecosystem

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td><strong>Ethical values</strong></td>
<td>Customs, oral traditions, knowledge and rituals attached to the use of the land and rivers; Iraqi tangible and intangible cultural heritage; an area of global importance.</td>
</tr>
<tr>
<td><strong>Recreation and tourism</strong></td>
<td>Canoeing, bird and wild-life watching, recreational fishing, archaeological site visitation, Marsh communities.</td>
</tr>
<tr>
<td><strong>Aesthetic</strong></td>
<td>Globally significant natural beauty.</td>
</tr>
<tr>
<td><strong>Educational</strong></td>
<td>Science, cultural awareness, specialized vocational training, public awareness of national, regional and global importance.</td>
</tr>
</tbody>
</table>

### Supporting services – the underlying processes that are necessary for the production of all other ecosystem services

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil formation</strong></td>
<td>Retention of sediment, recycling and supporting the health of the ecosystem.</td>
</tr>
</tbody>
</table>
In this part of my assessment I drew attention to the environmental variables of the marshlands, such as water quality, quantity, depth and hydrological connectivity. The variables that have more influence in keeping the system’s identity are also of the most concern by the key stakeholders in Iraq. Considering the spatial-temporal scales in this step is crucial to understand the system boundaries (Walker et al., 2004). It is important to depict ecological goods and services derived from the marshes as a stocks-and-flows framework that explicitly shows the advantages we get from the system (United Nations Integrated Water Task Force for Iraq, 2011). Flows refer to the products gained from the system such as water, reeds, fish catch, and water buffalo. While the stocks are refer to the system’s component that produces the flows such as healthy water. Sometimes, each stock can supply multiple flows like in the example of healthy water in the marshes that supports the entire aquatic environment (Walker et al., 2004).

As a result, stocks, from resilience thinking point of view, are the wealth of the system that has social, economic, and ecological values for the system on hands. Stocks of the system are the assets that need to be addressed carefully and then to be managed accordingly. Engaging suitable stakeholders helps to address or to define the systems goods and services and define stalks and flows, as well. Then stakeholders have to find interactions, tradeoffs, and linkages between those components (Walker et al., 2004) (see Figure 5). Each of these assets has their own critical threshold values. For example, water quality has different thresholds for different parameters that keep healthy fishing and rich reed forests. So the big question comes up here; what is /are the big

<table>
<thead>
<tr>
<th>Nutrient cycling</th>
<th>Returning phosphorus, sulfur and nitrogen to Iraq’s atmosphere, water and soils</th>
</tr>
</thead>
</table>

issue(s)? The issues that people are most concerned about. Or, what they value in their system? Discussions with participants are a key step to identify the resilience of what? And how the issue is connected across scales and domain?

_Disturbances to the system._ After identifying the set of systems components that represent the wealth of that system, we have to characterize what type of disturbance threatens it. As mentioned in Chapter I. Reviewing disturbances’ definitions in Chapter I, helped to define what type of disturbances the Mesopotamian Marshes are facing now? And to approach this, a brief historical review is efficient to identify the drivers and trends that happened in the past and led to major changes in the marshes. In fact, acknowledging and maintaining the disturbance regimes within their natural range of variation is necessary. However, the addition of anthropogenic disturbances, that we focusing on here such as upstream damming, might push the system into a different regime.

_Drivers and trends._ Reviewing related literature and engaging key participants help to draw a time line for events that happened in the Mesopotamian Marshes across scales (lower, focal, and upper scale). Addressing the time line for each scale is important to give insights about events that led to big changes in the system. Although, drawing a timeline is not within the scope of this research, it is a part of the entire assessment.

_Assessing Mesopotamian Marshlands’ resilience._ Generally, assessing resilience entails assessing the system’s specified resilience, general resilience, and transformability (Walker & Salt, 2012). It is an ongoing process that evolves continuously whenever new information is added. Assessing the system’s specified resilience falls within the scope of this work and it involves identifying the Threshold Matrix. I will explore how ecological components interact with the
social and economical values and attitudes of people and managers in the system. This will be done by developing a conceptual model of the most influential ecological, social, and economical variables in the form of three scales X three domains’ type of Threshold Matrix. The matrix shows the system’s behaviour depending on what interactions, trends, and linkages are taking place in the marshes that are leading to decreased marsh health and productivity. The focal scale in this study is the Mesopotamian Marshlands, but as a part of resilience assessment approach, it is important to define below and above scales because there are cross-scales interactions that influence the system’s dynamics in the focal scale (Walker et al., 2002). Additionally, I conducted a statistical analysis for unpublished recent salinity reports received from the Iraqi MOWR.

Limitations, delimitations of the study and potential biases of the methodological approach

Resilience assessments are usually limited by the available information (primary and secondary data). One way to deal with this limitation is to be as clear as possible about the question I am addressing. I am trying to apply an alternative approach to manage the Mesopotamian Marshlands ecosystem, but, no doubt, progress and improvement will take place by incorporating more up-to-date data within the system. Another limitation is the time factor for stakeholders as some of them are very busy people therefore engaging them in one session of discussion as advised by Walker and Salt framework is unpractical while working remotely. Separate interviews and discussion were sufficient as well to deal with this limitation. The security situation was another constraint in this study due to the continuously deteriorating situation in Iraq that affected by ability to interact with key informants. Also, due to the dangerous situation in Iraq, the study site is inaccessible; therefore, it was not possible to engage with other stakeholders. Nonetheless, this study will still provide valuable insights for the marshlands managers and it will form the basis for more subsequent discussion and analysis through the eyes of resilience concept.
Chapter III: Results

This thesis builds a specified assessment as a part of an integrated management framework put forth by Walker and Salt (2012) for managing the resilience of Mesopotamian Marshlands. Elaboration upon the ecological thresholds for environmental parameters such as salinity, biodiversity, water depth, and water flow and their influence on the social and economical elements of the system is addressed. Environmental components are usually easier to address and measure than social ones (Shedroff, 2009).

The Resilience Assessment Framework

As described in Chapter II, the analysis in this work includes defining the system and then assessing its specified resilience. The following sections outline the results of the analysis.

Defining and describing the marshlands. Engaging key informants is crucial in this step because it: 1) provides a greater depth and breadth of data collection and 2) should facilitate the implementation of new management plans if ‘buy in’ is achieved through engagement. The Ministry of Water Resources in Iraq (MOWR) is a source of information that provides me with salinity reports in the marshes for the period between 2010 and 2013.

What is the big issue in the SES? All participants mentioned drought and decreased water quantity and quality a since the 1970s as primary issues in the SES. These factors have led to deterioration of the entire system.

Scales (System boundaries). Scales are spatial-temporal. In terms of spatial scales, the Mesopotamian Marshlands in southern Iraq is considered an ecosystem, but it is a part of a larger watershed that encompasses parts of Turkey, Syria, Iran and Iraq. On the other hand, each marsh is
an ecosystem at a scale smaller than the entire Iraqi marshlands. Choosing the scale is strongly
dependent on what scale is undergoing an issue and, as a result, needs a resilience assessment
(Walker & Salt, 2012). In this study, the scale of interest, the focal scale, is the Mesopotamian
Marshlands of southern Iraq (A. Douabul, personal communication, February 2, 2015). In this case
study, the Iraq central government has the authority to manage the marshlands in Iraq; the focal
scale, while local government, provincial councils and some of national and nongovernmental
organizations are involved in managing the scale below the focal scale; a marsh within the entire
marshes. Internationally, the governments of upstream jurisdictions are controlling their own
catchment areas within their national boundaries (United Nations Integrated Water Task Force for
Iraq, 2011). In terms of the temporal scales, this study collected and analyzed qualitative data for a
period from 1990 to 2013. The quantitative data received from MOWR are for 2010 to 2013.

**People and governance.** On the national scale and during the period of Saddam’s tenure,
1979-2003, the Iraqi Ministry of Irrigation was responsible for controlling the irrigation in the
catchment area inside Iraq. After Saddam’s government fell in 2003, the ministry was reformed
and expanded to consider further development. Currently, the Ministry of Water Resources
(MOWR) represents the central government institution that controls and manages the Tigris and
Euphrates streams and their tributaries that feed the marshlands (Alwash, 2013). In an interview
with one of research informants, she mentioned that the ministry strives to effectively distribute
water in Iraq, but it is highly restricted by the amount of water that released to Iraq from upstream
countries, such as Turkey, Syria, and Iran. Another key informant claims that an unplanned release
for the Iraqi water share to unsuitable areas is a reason for wasting the available water and
eventually led to the current deteriorated situation.
At the catchment scale, the long journey of water from its origin far in the north toward its final destiny downstream imposes stress on water quantity and quality that feed the marshes. Two-thirds of water courses go through the highlands of eastern Anatolia in Turkey and the valleys of the Syrian and Iraqi plateaus before entering the arid plain of Mesopotamia (Kibaroglu, 2002). The Euphrates River feeds both the Central and Hammar Marshes and historically it brings 36 bcm / year to Iraq (Mazlum, 2009). Since 1970, the series of dams built on this river in Turkey, Syria, and Iraq have reduced the Iraq water share by one-third to around 19 bcm, in 1990 (Alwash, 2013). After 1990, the construction of the irrigation work in Iraq had started and gradually impacted the water quantity reaching the downstream marshes. The Tigris River that feeds the Central and Hawizeh Marshes has an average flow around 49 bcm / year (Mazlum, 2009). Turkey also impacted the Tigris River by building the gigantic Ilisu dam that proposed to hold half of Turkey’s Tigris annual flow. In addition, Iran controls the headwaters of Tigris main tributaries and it releases 22 bcm from the Tigris water to Iraq. Altogether, building dams and irrigation works in the upper reaches impose a significant threat to the existence of SES of Mesopotamian Marshes downstream without appropriate water sharing agreement. A research informant mentioned that there has not been much progress beyond the re-establishment of a Joint Technical Committee between Turkey, Syria, and Iraq in 2008 to share water data and sharing research for water issues in the area. She also mentioned that the government efforts to establish new treaties have been hampered by the unstable political and security situation. Maintaining the previous treaties is challenging for the same reasons.

In terms of lower scale, each marsh (Central, Hammar, and Al- Hawizeh) is governed by the local authorities appointed by the central government in Baghdad. The local government is restricted by the water share released by the upstream countries. The complex system nonlinearity
affects the marsh Arabs and their ecosystem in the marshes in the lower scale of the wetland. This illustrates how, in a specific time scale, events on a small scale can be impacted by global scale or vice versa (Bar-Yam, 1997).

**The resilience of what?** As mentioned in the Chapter III, to approach this part of the assessment, a scheme of a system’s goods and services is typical because it shows what people directly and/or indirectly gain and value from their ecosystem (Walker & Salt, 2012). Generally, the Marshlands deliver a wide range of benefits that are vital to the existence and well-being of indigenous people and all Iraqis, such as food, clean water and climate control (United Nations Integrated Water Task Force for Iraq, 2011). Table 1 shows the details of those goods and services that marshlands supply to Iraqis at the focal scale (The Mesopotamian Marshlands). Reviewing those goods and services helps the stakeholders to draw attention to the environmental variables that have more influence in keeping the social-ecological identity of marshes (United Nations Integrated Water Task Force for Iraq, 2011). As shown in Table 1, ecosystem services provided by or derived from the Iraqi Marshlands in the focal scale are connected to higher and lower scales (e.g., water). Water that is used for daily life purposes in Mesopotamian Marshes is affected by upstream users (international), by the focal scale in Iraq, and by the lower scale inside the marshes. Upstream damming affects water security in lower Mesopotamia. At the focal scale, poor oil extraction practices are occurring inside the marshes and have a major impact on the entire system (A. Douabul, personal communication, February 2, 2015). While at the lower scale, traditional rice cultivation often includes poor agricultural practices that consumes a lot of the Iraq water share and creates poor status of the rice-farming community (ELARD, 2013). Iraq consumes more than 80% of its water capital for agriculture (Al-Ansari, 1998). The Iraqi side has declared that poor water management contributes to Iraq’s water shortage, and wise water usage would be the best
current alternative to increase water availability for all people (Shatib, 2011; A. Douabul, personal communication, February 13, 2015). Moving between those categories can be a useful way of identifying the marshes’ services that Madan people values in their ecosystem and accordingly the management authorities can prioritize them.

**Disturbances to the system.** After identifying the set of system goods and services that represent the wealth of the Mesopotamian Marshes, we now introduce the types of disturbance that threatens them. Since the fall of Saddam Hussein’s regime, the wetland has faced many disturbances that hamper the restoration processes, such as water scarcity, lack of efficient management, and poor oil extraction practices, one of the research informants claims. The consequences of those problems include increased water salinity and ecological fragmentation (Al-Ansari & Knutsson, 2011). Those disturbances can be categorized, according to Walker and Salt (2012) classification, into the following:

- **Anthropogenic Disturbances:** Two main anthropogenic disturbances can be observed in the Mesopotamian Marshlands, the water scarcity due to upstream and downstream damming (United Nations Integrated Water Task Force for Iraq, 2011) (see Figure 4) and the massive oil and gas development in Southern Iraq (A. Douabul, personal communication, February 2, 2015). On the larger scale, through the 20th century, construction of dams with a huge capacity to hold waters, such as GAP project at the upstream parts of the Euphrates River in Turkey and many other hydraulic works in Syria, played a fundamental role in controlling the floods (part of the natural disturbance regime) and minimizing the flow of the main rivers in the lower wetlands (Al-Ansari & Knutsson, 2011). As a result, the Mesopotamian Marshes are no longer fed by Tigris and Euphrates Rivers flood pulse (Warner, Douabul, & Abaychi, 2010). For that reason,
salinity has started to increase as a result of the severe decrease in the annual flooding and increase evaporation rates in that arid area (Al-Ansari & Knutsson, 2011). Moreover, on the national scale, the drainage works inside Iraq amplifies the water scarcity issue. Although, draining activities in the catchment area began in the 1950s to reclaim land for agriculture and oil exploration, Saddam Hussein’s action plan to drain the marshes in the early 1990s played a key role in expanding and accelerating the destruction of the marshes (Al-Ansari & Knutsson, 2011; United Nations Integrated Water Task Force for Iraq, 2011; Adriansen, 2004). The second important reason behind the continuous deterioration of the marshes is the massive oil and gas development in Southern Iraq. The giant Majnoon Oil Field, one of the largest oilfields in the world, is located under the marshes. Some world’s largest oil and gas companies are developing projects in this oil field which creates another potential threat for the water availability for the people. Huge quantities of water are needed for production. Although oil companies are trying to reduce negative impacts their services might cause to the ecosystem, direct risks to the water availability and ecosystem biodiversity still exist

- Stochastic Social Disturbances: Since 1980, wars represent a series of actions that have disturbed all social-ecological systems in Iraq. The wetland of Iraq is an ecosystem that has been shaped by wars and challenging security issues repeatedly (Partow, 2008). Although the full impact is not always straightforward or instantly clear, long term ecological consequences will be apparent years after their occurrence (Worldwatch Institute, 2014). Moreover, another unpredictable disturbance has been added to the system by controlling the radical group of the Islamic State of Iraq and Syria (ISIS) on some dams in an area between northwest Iraq and east Syria. The effect of ISIS as a new
pressure to the area can make the system more vulnerable to already existing environmental disturbances; as a result, it will undesirably change the rich picture in the lower Mesopotamia.

*Drivers and trends.* Defining the drivers that have an effect on system’s controlling variables is a key step to define the system’s thresholds. Political decisions for upstream water storage, central government strategies, and climate change are key drivers lead to the present issue, one of the research informants claims.

*Assessing Mesopotamian Marshlands’ resilience.* Although specified resilience, general resilience, and transformability are three related aspects that need to be identified in this step of any resilience assessment framework (Walker and Salt, 2012), specified resilience is the part that falls within the scope of this study. Walker and Salt (2012) state that Known Thresholds, Thresholds of Potential Concern, Developing Conceptual Model, and Analytical Models are helpful tools could be used in getting to a first-cut examination of possible thresholds in SESs. Resilience is not about including everything in the assessment, but it is an evolving process that develops as new information becomes available (Walker and Salt, 2012). It is about identifying the most critical variables at a system scale. Known Thresholds and Thresholds of Potential Concern are the focus of the current research. This was deemed reasonable for the scope of a thesis.

*Defining the Mesopotamian Marshes thresholds matrix.* Based on literature review, interviews with participants, previous description of ecological goods and services and the system’s components in terms of scales, people and governance, disturbances to the system, and drivers, an outline of probable controlling variables and thresholds can be defined. In establishing the Mesopotamian Marshes thresholds matrix, I am largely elaborating on the salinity parameter.
However, the analysis touches on several other controlling variables that operate across scales and domains in the concerned SES. Figure (5) illustrates a representation of Known Thresholds and Thresholds of Potential Concern’s matrix that focuses on possible thresholds in the system at different scales and domains. The matrix shows multiple thresholds and their interactions at three scales; a marsh within the entire marshes, Mesopotamian Marshes, and the catchment area, and within different domains; biophysical, social and economical.

In the Mesopotamian Marshes social-ecological system, assessing specified resilience involved identifying the controlling variables that might have threshold effect and then identifying the interactions and linkages between them. Figure 5 is a simplified model for the complexity on the ground. I am focusing on the salinity variable and its connections because salinity, as one of the environmental controlling variables, has the most important and influential impact in the marshes’ restoration assessment efforts (AlMaarofi, Douabul, & Al-Saad, 2012). The water level threshold has been always considered as a dominant variable on determining the biodiversity aspects in the marshes (Warner, Douabul, & Abaychi, 2010). This parameter has been severely changed in the Iraqi marshes (Warner, Douabul, & Abaychi, 2010). Crossing the threshold of water level parameter in a SES often leads to a “cascading effect” in which multiple thresholds across scales and domains may be breached (Kinzig et al., 2006). Currently, the salinity threshold appears to be critical in this system and dropping below a critical value will cause cascading effects to the system (see Figure 5). Based on system diagram shown in Figure 5, the most apparent three trajectories are discussed. The 2010 Food and Agriculture Organization of the United Nations (FAO) report regarding the water quality impacts from agriculture mentions that 1.75 million ha of the area in southern Iraq is saline. Salinity is a serious problem in Iraq now (AlMaarofi, Douabul, & Al-Saad, 2012).
Figure 5. Thresholds Matrix in the Mesopotamian Marshes of Southern Iraq. Rectangles on the left denote the system’s domains; rectangles on the top denote the system’s scales. F=focal scale; B= below scale; A=above scale while En=environmental domain; E=economical; and S=social domain. Red arrows represent trajectory (1), green arrows represent trajectory (2), and blue represent trajectory (3).
Salinity needs to be addressed unconventionally in the lens of resilience thinking. The Mesopotamian Marshes as a SES cannot be clearly understood by pulling it apart; rather, it is about gaining understanding by acknowledging the various components and their interactions altogether in a holistic way (Reynolds & Holwell, 2010). Therefore, the threshold matrix presented in figure 5 shows salinity as the most influential controlling variable because it is highly connected with the other variables in the system across scales and domains. Undoubtedly, the interactions and connections between these levels add more complexity to the system and therefore it requires unconventional management approach that sees the issue in several scales simultaneously (Berkes, 2003).

Defining the controlling variables and locating the threshold values is not an easy task, but it is an evolving process (Walker & Salt, 2012). Working remotely and the deteriorated security situation in Iraq during the study period prevented me from engaging more influential stakeholders. Engaging more participants would be very useful to expand the matrix and find new interactions between its variables. Figure 5 is a first snapshot for what the threshold matrix for specified resilience in the Mesopotamian marshes. There is always a scarcity of both ecological and social data, relating to the Iraqi Marshlands due to unstable security situation (Dempster, 2007). Researchers in Iraq and all over the world can get a good start from this threshold matrix to build a complete resilience assessment framework. Full resilient assessment is essential for the Iraqi government to make the best decisions in the marshes.

_The MOWR salinity levels’ report in the Mesopotamian Marshes_. Reviewing the data received from the MOWR in Iraq shows that the situation in the Mesopotamian Marshes is deteriorating. Although previous reports from the United Nations Environment Programme mention that some indicators like the vegetation cover and water surface area have increased by
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about 58% since 2003 (UNEP 2005), fluctuation of marsh environmental condition in the years following 2003 re-flooding is clear (CIMI 2010a). Results of my analysis of the MOWR salinity reports confirm the increasing fluctuation in salinity levels for the data recorded in all marshes, within a short time frame; from 2010-2013 (see Figure 6)

Re-flooding the marshes was a valued spontaneous reaction from local people but sometimes not well-understood actions occur in a small part of the system might create undesirable consequences in other parts of the system such as the amplified salinity issue in our case study. The system keeps surprising us. Garstecki & Amr (2011) claim that overoptimistic expectations of restoring healthy marshes, following the re-flooding, are inapplicable now. The bright side of the marshes situation should not hamper the government efforts to promptly adapt a robust resilience assessment framework to contain the increasing salinity issue in the area. Information about the salinity levels in the Mesopotamian Marshes between 2010 and 2013 are expressed in Tables 2, 3, 4, and 5 in four months; February, April, July, and November. Climatologists usually use months to represent the seasons. In Iraq, winter is considered February; spring is April; summer is July; and fall or autumn is November. As seen in Tables 2, 3, 4, and 5, salinity is fluctuating and increasing in almost all monitoring stations during the time of data collection. Before the 1990s, salinities were generally in the oligohaline (0.5 to 5.0 PSU; each 1 PSU ≈ 1 gm/l) range in the three marshes with some low mesohaline area within Al-Hammar marsh (Hussain, & Grabe, 2009). As seen in Table 2, 3, 4, and 5, salinity began to exceed the range before 1990s. For instance, area in Al-Hammar marsh, 8601 and 6210 mg/l (≈ 8.6 & 6.2 PSU) were recorded in spring and summer 2011 (see Table 3). One of the research participants mentioned that, during the summer time (July), around 12 mg/l salinity level in Al-khemeeseeya (a monitoring station in Al-Hammar marsh) were recorded. Similarly, numbers higher than the maximum of 1990s were
recorded in 2012 and 2013 in Al-Hammar marsh (see Table 4 & 5). More importantly, reviewing salinity levels in the Mesopotamian Marshes in Tables 2, 3, 4, and 5, show evidence of increasing the minimum salinity level (740 mg/l ≈ 0.74 PSU) in comparison with the minimum value before 1990s range (0.5 PSU).

Table 2

*Salinity levels in the Mesopotamian Marshes in 2010*

<table>
<thead>
<tr>
<th>District or Zone</th>
<th>Average Total Dissolved Solids TDS (mg/l) Jan., Feb. and March 2010</th>
<th>Average Total Dissolved Solids TDS (mg/l) April, May and June 2010</th>
<th>Average Total Dissolved Solids TDS (mg/l) July, August and Sept. 2010</th>
<th>Average Total Dissolved Solids TDS (mg/l) Oct., Nov. and Dec. 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hammar marsh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Al-khemeeseeya</td>
<td>3250</td>
<td>3885</td>
<td>4371</td>
<td>4072</td>
</tr>
<tr>
<td>• Al-hameedi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5844</td>
</tr>
<tr>
<td>The Central marshes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AZ24</td>
<td>913</td>
<td>740</td>
<td>1209</td>
<td>1295</td>
</tr>
<tr>
<td>• Abu Sobat</td>
<td>-</td>
<td>4247</td>
<td>2047</td>
<td>2655</td>
</tr>
<tr>
<td>Al-Huwaiza marsh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Al-adl</td>
<td>753</td>
<td>770</td>
<td>823</td>
<td>760</td>
</tr>
<tr>
<td>• Al-kassara</td>
<td>1427</td>
<td>1079</td>
<td>1200</td>
<td>1543</td>
</tr>
<tr>
<td>• Um Al-nia'aj U3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>753</td>
<td>763</td>
<td>742</td>
<td>837</td>
</tr>
</tbody>
</table>

Table 3

*Salinity levels in the Mesopotamian Marshes in 2011*

<table>
<thead>
<tr>
<th>District or Zone</th>
<th>Average Total Dissolved Solids TDS (mg/l) Jan., Feb. and March 2011</th>
<th>Average Total Dissolved Solids TDS (mg/l) April, May and June 2011</th>
<th>Average Total Dissolved Solids TDS (mg/l) July, August and Sept. 2011</th>
<th>Average Total Dissolved Solids TDS (mg/l) Oct., Nov. and Dec. 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hammar marsh</td>
<td>• Al-khemeeseeya 5772</td>
<td>5611</td>
<td>5147</td>
<td>4486</td>
</tr>
<tr>
<td></td>
<td>• Al-hameedi 5460</td>
<td>6210</td>
<td>8601</td>
<td>5375</td>
</tr>
<tr>
<td>The Central marshes</td>
<td>• AZ24 1131</td>
<td>1249</td>
<td>1306</td>
<td>1334</td>
</tr>
<tr>
<td></td>
<td>• Abu Sobat 3488</td>
<td>4688</td>
<td>3613</td>
<td>3221</td>
</tr>
<tr>
<td>Al-Huwaiza marsh</td>
<td>• Al-adl 885</td>
<td>820</td>
<td>783</td>
<td>870</td>
</tr>
<tr>
<td></td>
<td>• Al-kassara 2495</td>
<td>1577</td>
<td>1463</td>
<td>1225</td>
</tr>
<tr>
<td></td>
<td>• Um Al-nia'aj U3 1010</td>
<td>920</td>
<td>753</td>
<td>747</td>
</tr>
</tbody>
</table>


Table 4

*Salinity levels in the Mesopotamian Marshes in 2012*

<table>
<thead>
<tr>
<th>District or Zone</th>
<th>Average Total Dissolved Solids TDS (mg/l) Jan., Feb. and March 2012</th>
<th>Average Total Dissolved Solids TDS (mg/l) April, May and June 2012</th>
<th>Average Total Dissolved Solids TDS (mg/l) July, August and Sept. 2012</th>
<th>Average Total Dissolved Solids TDS (mg/l) Oct., Nov. and Dec. 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hammar marsh</td>
<td>• Al-khemeeseeya -</td>
<td>6782</td>
<td>6726</td>
<td>5543</td>
</tr>
<tr>
<td></td>
<td>• Al-hameedi</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 5

**Salinity levels in the Mesopotamian Marshes in 2013**

<table>
<thead>
<tr>
<th>District or Zone</th>
<th>Average Total Dissolved Solids TDS (mg/l)</th>
<th>Average Total Dissolved Solids TDS (mg/l)</th>
<th>Average Total Dissolved Solids TDS (mg/l)</th>
<th>Average Total Dissolved Solids TDS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hammarr marsh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Al-khemeeseeya</td>
<td>5862</td>
<td>4980</td>
<td>6687</td>
<td>-</td>
</tr>
<tr>
<td>• Al-hameedi</td>
<td>5823</td>
<td>5443</td>
<td>6157</td>
<td>4485</td>
</tr>
<tr>
<td>The Central marshes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AZ24</td>
<td>1157</td>
<td>1269</td>
<td>1523</td>
<td>1180</td>
</tr>
<tr>
<td>• Abu Sobat</td>
<td>3078</td>
<td>3458</td>
<td>3001</td>
<td>1975</td>
</tr>
</tbody>
</table>

Al-Huwaiza marsh

- Al-adl 902 903 890 870
- Al-kassara 1337 1817 1700 1125
- Um Al-nia'aj U3 893 1057 957 807


*Figure 6.* Salinity levels for the period from 2010 to 2013 during all seasons in Al- Hammar marshes (a) Central marshes (b) and Al-Huwaiza marshes (c). Derived from MOWR data, Iraq.
Hydrologically, the Iraqi marshes have a “flood pulse” system that matches most riverine, coastal, and deltaic wetlands systems (Middleton 1999). The flood pulse in the Iraqi marshes shows seasonal changes in water levels during the year and it repeats itself again in the next year (Warner, Douabul, & Abaychi, 2010). Annual water level changes and their influence on other systems’ variables, such as salinity, interact to sustain the marshes. Annual variation of water entering the marshes is essential to keep the marshes resilient. But, water level in Iraq has been mainly restricted by regional water allocation at the larger catchment scale (see Figure 5). The central government strategies have their own influence at the national scale, as well (see Figure 5). Statistical analysis for the data received from MOWR demonstrates that Al-Hammar marsh is experiencing the highest salinity levels during the all year seasons, followed by the Central marshes, and Al-Hawizeh marshes (see Figure 7). Although only one third of the original coverage of Al Hawizeh marshes has remained, it underwent a relatively less drastic reduction in its surface area than the Central and Al-Hammar marshes (Partow, 2001).
Figure 7. Variations in salinity levels for all marshes from 2010 to 2013 during Winter (a) Spring (b) Summer (c) and Fall (d). Derived from MOWR data, Iraq.
Chapter IV: Discussion

In this chapter I discuss the proposed framework in the context of a resilience thinking approach. Analysis of thresholds requires addressing the system’s complexity and nonlinearity across different scales and domains (Groffman et al., 2006). Therefore, the discussion will be in the form of combining all information collected to describe the system and then assessing its specified resilience within Walker and Salt (2012) resilience assessment framework. Although specified resilience includes a four-step frame, addressing any one of them helps to put a complete resilience assessment framework in practice for the first time in Iraq. It is an iterative process that will evolve and become more refined as new information becomes available. Walker and Salt (2012) affirm that what we achieve from assessing specified resilience is an outline of scales-and-domains thresholds matrix which is essential to recognize the cascading effects and the hierarchy of thresholds within those dimensions in the system.

General Analysis for the Mesopotamian Marshes through Resilience Lens

The Mesopotamian marshlands in Iraq often referred to as the “Garden of Eden” are of fundamental importance to Iraq and the entire region. The marshes, as a system, provide a wide range of environmental, social, and economical services to the entire region. These marshes sustained many forms of life for the last 9000 years and they have long served as the historic home of Marsh Arabs – the Ma’dan’s culture. They sustained a unique lifestyle depending on the marshes’ abundant resources for millennia. Most of the marshes are privately owned by Ma’dan tribal people. However, the central government in Iraq owns some areas and reserves. Although the construction of many water controlling structures in the riparian countries has occurred since 1950s, the marshes continued to operate a flood pulse system necessary for proper ecological
function. However, extensive upstream damming that started in the 1970s, and the Saddam Hussein action plan to drain the marshes in the early 1990s, has pushed the SES towards critical system thresholds that threaten long term sustainability. Moreover, one of the key informants mentioned that after Saddam Hussein’s fall in 2003, government instability and bad security prevented the creation of new strategic water agreements and existing agreements are largely ineffective.

This work took the Mesopotamian marshes as a focal scale, while each marsh and the catchment area are the scales below and above, respectively. Therefore, water allocation from higher scales plays a vital role in drawing the current picture in lower scales; in each marsh. The system diagram presented in Figure 5 is a helpful tool in capturing some of the marsh system complexity. The non-linearity of self-organizing Mesopotamian marshes SES is an important characteristic of the complex system. Identifying the current most critical controlling variables across scales and domains is a crucial step in assessing resilience of the SES. Threshold values within those controlling variables are critical numbers to be identified by the managing authorities in Iraq. Figure 5 clearly represents salinity as one of the environmental controlling variables that has the most important and influential impact in the marshes’ restoration assessment efforts.

From the resilience thinking point of view, I selected salinity as a prime parameter in the current situation of the Mesopotamian SES. The initial network analysis presented in Figure 5 confirms that salinity variable has more influential ties and linkages to the other controlling variables across scales and domains of the network as a whole. Hence, being in the position of high centrality, salinity is powerful critical parameter that should get the focus of the authorities in Iraq now. The high level of centrality means that there are some variables in the SES network that have a significantly higher number of connections and have links that go beyond their scale and
domain (Janssen et al., 2006). By highlighting the most critical parameter(s), natural resource managers can adaptively monitor, intervene, and manage the resilience of some goods and services that need to be managed urgently in the marshes. In the future, more formal network analysis is required to identify the most powerful variables in the marshes from the Iraqi authorities.

**Salinity thresholds and some important linkages in the Mesopotamian Marshes.**

Monitoring and managing critical variables in the system increases the potential to achieve a ‘Safe Operating Space’ (Walker and Salt, 2012). To the extent that this holds, acknowledging the salinity threshold and the trajectories that they might push the system into is a good tool for managers to transfer the system into more resilient configuration. Salinity is a critical variable and, as shown in MOWR report, beyond (0.74 to 8.6 PSU) the marshes maybe highly threatened with a collapse. When asked, in one of his presentations, “what do you do about thresholds?” Brian Walker (2011) answered that identifying the most influential ones helps to develop policies to manage them; by avoiding them, moving them, and even crossing them, in favour of systems resilience. Figure 5 illustrates that there are some known thresholds and TPC that are linked to each other in the marshes. The crossing of water volume threshold entering Iraq due to events have occurred from mid-1970 to early-1990 ultimately led to the breaching of salinity thresholds. Research informants have agreed that the focal scale, i.e., Mesopotamian marshes (F/En) is threatened by the high salinity level in the lower scale (B/En) that has irreversibly impacted many areas. Figure 5 illustrates many linkages that the salinity variable mediates. The following trajectories are examples of some apparent linkages.

**Trajectory (1).** Figure 5 shows how environmental controlling variables, such as water condition (F/En), vegetation cover (F/En), higher aquatic macrophytes (F/En), and Ecosystem productivity (F/E) in the entire Mesopotamian Marshes SES depend on salinity levels (B/En) in
each marsh. Salinity levels (B/En) have mainly increased due to decrease in water quantity entering the marshes (Hussain, & Grabe, 2009) (see Figure 5). On the one hand, Tigris & Euphrates flow levels (A/En) are one of the most important factors that determine salinity (B/En) at the marsh scale. Decreasing water input leads to reduction of water output downstream in the marshes outlets and eventually leads to increase of the Gulf tide via Shatt Al-Arab River (AlMaarofi, Douabul, & Al-Saad, 2012). Decreasing the Shatt Al-Arab River tide is allowing the Gulf saline water to go deeper in the marshes than before, when the input was higher. Thus, salinity is continuously increasing in the area (AlMaarofi, Douabul, & Al-Saad, 2012).

Simultaneously, this is a reciprocal process and, accordingly, the gradually increasing salinity (B/En) in the marsh scale does affect the Gulf coastal marine environment (A/En), in higher scale. On the other hand, Tigris & Euphrates flow levels (A/En) themselves are directly influenced by regional water allocation (A/S), water control structure (A/S), and regional climate (A/En). Therefore, water condition (F/En) and many other environmental variables in the focal scale are influenced by salinity levels (B/E) that are shifted due to changes that take place at scales higher than the focal scales.

**Trajectory (2).** Central government strategies (F/S) in the Mesopotamian Marshes play another important role in the existence of the marshes. The central government in Iraq, represented by the MOWR, controls the distribution of Iraq water share among the three main marshes; Al Hammar, Central and Al Hawizeh marshes, and eventually manage the water quantity entering (B/En) them. The water quantity entering the marshes is connected directly to the increasing salinity levels (B/En) and, ultimately, affecting the entire SES. The security situation (F/S) plays a vital role in the government strategies (F/S) because safety is crucial for any project the government planned for. The poor security situation and political instability hamper the central
government efforts to create new treaties for regional water allocation (A/S) with the riparian countries (S. Alwash, personal communication, February 25, 2015). The function of the national water control structures (F/S) at the focal scale has been imposed by the government due to limited Iraq water share which is mainly controlled by Regional Water Allocation (A/S) and Water Control Structure (A/S). There are significant challenges for any Iraqi government in power sue to: poor land use (F/E) which leads to poor agricultural practices (B/E), Water buffalo grazing & livestock (B/E), and poor fishing practices (B/E). In addition, the government is responsible for poor infrastructure (B/E) and uncontrolled oil extraction practices (F/E). For all Iraqis, this is an unacceptable situation after more than eleven years since the US invasion. As a result, the central government strategies have a direct and indirect impact on the salinity levels of the marshes.

**Trajectory (3).** Salinity levels (B/En) have their direct and indirect impact on the marsh Arabs (Madan) population (B/S). Marsh Arab livelihood is closely linked with fresh water availability. Marsh Arabs settlements and activities (B/S) rely on fishing (B/E), water buffalo grazing & livestock (B/E), transportation through the water ways (B/E), and agricultural activities (B/E) as economic generation sources. When the water becomes more saline, their settlements and activities (B/S) will get impacted (B/S). As a result, decreasing marsh Arab populations (B/S) will impact the financial viability (B/E) of the marshes in the lower scale because the Mesopotamian Marshes as a SES will lose one pillar of its sustainable existence; the social component. In an interview with one of key informants, he raised the issue of mosquitoes preventing marsh families from sleeping well. From the systems thinking point of view, he connected the elevated salinity levels (B/En) with the degradation of many fish species (Biodiversity (B/En)), such as *Gambusia*, also known commonly, as mosquito fish. It is obvious from the name that the diet of this fish consists of large numbers of mosquito larvae. The absence of this kind of fish is a scientific reason
behind the increase in the mosquito population in the marshes and eventually being an annoying problem and a threat of serious diseases for the Marsh Arab families. The lack of social part means a decrease in the ability of the SES to generate sufficient income to meet the people’s needs.

Additionally, poor infrastructure (B/E) that results from corruption that is pervasive at all levels of government in Iraq is another important factor that hampers the restoration of the marsh Arab previous life and livelihood, a research informants claims. Transparency International, the global coalition against corruption, indicates that Iraq is close to the higher limit with a rank 170 out of 175 in The Corruption Perceptions Index tool (Transparency International, 2014). He explained an example that links the corruption and the salinity issue in the marshes. He claims that some investors transform the area into private fish lakes and they do open the water according to their preferences. Therefore when they release water into the marshes, it will be loaded with high salt content that eventually adds more pressure to the marshes SES. The authorities have to enforce restrictions upon such kind of investors. In such a social and political environment, the marsh Arab population will decrease gradually in the area and, consequently, threaten the existence of the Mesopotamian SES. The Mesopotamian Marshes have suffered a lot from the accessibility issue, unsafe security situation (F/S) and being as a scene of fights (B/S) since 1980. As a result of the above, Marsh Arab preferences and values (B/S) have changed dramatically. In an interview with one of Marsh Arabs, he mentioned that marsh Arabs are not willing to come back to live in the marshes due to the poor infrastructure (B/E) and deteriorated living standard. He added, some people do very profitable business from the agriculture of dried marshes since 1990s and they would never let their business go for the sake of environment well being. Parts of the marshlands are still in use as agricultural areas and the owners or the local authorities are unwilling to leave them due to the high monetary advantages (Al-Ansari & Knutsson, 2011). Such unrestricted
actions are reasons behind the marshes transformation. Currently, large areas in the marshes are dominated by *Tamarix* and *Suada* trees and shrubs which indicate that a threshold has clearly been exceeded and, as a result, previous marshes have been replaced by a new ecosystem (Warner, Douabul, & Abaychi, 2010).

Consequently, people’s values and preferences are dramatically changing in a way that is completely against the restoration efforts, unless the government in Iraq takes a serious action in this regard. Two of the research informants mentioned detrimental bird hunting and fishing practices, respectively, that have recently been occurring in the marshes. This is also due to inappropriate government strategies (F/S). A research informant also mentioned that some religious leaders gave Fatwa (Fatwa is the legal opinion that a trusted religious leader can give on Muslims’ issues) that prohibits poaching. This is a positive action in a religiously conservative society like the Marsh Arabs. While another claims Fatwa is not a plausible way to enforce law and regulations in the chaos of Iraqi, the government should practice its power to enforce protection laws. He added that some people will follow the Fatwa but what about the people who are making fortunes from such practices.

**The MOWR salinity levels’ report analysis.** – From the resilience thinking point of view, threshold values cannot be acknowledged until they get passed or they get closer to passing. As seen in Tables 2, 3, 4, and 5, within limited time scale; between 2010 and 2013, salinity levels in the three marshes are significantly fluctuating. Whenever a system’s dynamics change and fluctuate more than usual, it indicates that there is a pending regime shift (Carpenter and Brock 2006). Therefore, the kind of system variability that has been introduced in figure 6 and 7 provides early warning that a threshold is being threatened in the Mesopotamian Marshes. It can be noticed that the salinity thresholds have been changed dramatically in comparison with the 1990s records;
from 0.5 to 5.0 PSU. Analysis for the current MOWR report shows that recently measured salinity values can be determined between (0.74 to 8.6 PSU). Figure 5 clearly illustrates some of the system’s complexity that sits behind the deteriorating situation of the Mesopotamian Marshes. Tigris & Euphrates flow levels, regional climate, regional water allocation, and regional conflicts, such as emergent of ISIS control, are controlling variables that affect the system from higher level. While, the central government strategies is the most significant player affecting the existence of the marshes within the focal scale. In the lower scale, salinity issue that has been raised due to across scales and domains reasons, Marsh Arab preferences and values, and Marsh Arab population are reasons behind the marshes, as a SES, survival.
Chapter V: Conclusions and Recommendations

Conclusions

Restoration of the vast area of the Mesopotamian Marshes social-ecological system is vital to the catchment area and to Iraq, in particular. Many efforts have occurred to restore and manage the marshes in southern Iraq since the fall of Saddam Hussein’s regime in 2003. However, an integrated social-ecological approach that recognizes the marshlands as a complex social-ecological system (SES) was absent. Building such an integrated assessment framework for the restoration of the Marshlands using a resilience thinking approach would greatly increase the potential for success. It helps to acknowledge the Mesopotamian Marshes’, as a self-organizing system, complexity, uncertainty, and non-linearity features and filling the gaps in knowledge to manage it wisely.

This work describes the system and identifies its specified resilience as a part of an integrated management framework put forth by Walker and Salt (2012) for managing the resilience of the southern Iraqi wetlands. Defining some key controlling variables and elaborating upon the salinity parameter and its thresholds and influence on other environmental, social and economical elements, across scales and domains, are addressed. The work identifies some linkages that connect the key controlling variables in the system. Moreover, from resilience thinking point of view, analysing MOWR salinity reports indicate that the recent system’s variability, in respect to increasing and fluctuating in the salinity levels, suggests an impending regime shift.

Recommendations

This study represents the basis for additional work in resilience assessment of the Mesopotamian Marshes in Iraq. Researchers need to complete applying the resilience assessment framework to the case study of the Mesopotamian marshes. Applying resilience thinking to real-
world situation, such as the Iraqi wetlands, helps to explore the practicality of how systems can be managed to promote resilience. Managers have to be aware that irreversible threshold change might occur if not an integrated social-ecological assessment has been applied. Threshold matrix and extensive thresholds monitoring plans can be used as a quality index tool that shows how far the system is from the closer transformation. In addition, addressing the system’s linkages is an important tool that assists authorities in Iraq to know where to intervene in the system effectively and make it more resilient in the face of multiple shocks and disturbances.
References


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