CHAPTER ONE

INTRODUCTION

1.1 Background and statement of the problem

Fisheries in developing countries are experiencing serious over-harvesting stress and often consequent collapse of fish resource stocks due to many market and policy failure situations such as poor management and open access conditions (Andrew *et al*. 2007; Sterner, 2003). The number of under-harvested inland fish stocks has decreased from 40 % in 1990 to 23 % in 2004 (Millennium Ecosystem Assessment, 2005). This was mainly driven by the rapid increase in fish consumption, which has doubled in developing countries in the past three decades due to increase in population (MEA, 2005). On the other hand, the growth in the international fish trade (exporting fish from developing to developed countries) increases the price of fish on local markets due to demand from exporters. This therefore results in illegally-caught fish entering markets due to increasing consumer demand that is met by increasing production, putting serious pressure on fish stocks (DFID 2005; Policy Brief 7). Particularly, African tropical fresh water lakes are believed to be fully exploited and even over-fished in many parts (MEA, 2005). This presents a big threat to the capacity of these fishery ecosystems to continue providing for the livelihood of many communities that are highly dependent on them (FAO, 1999a; UNEP, 2010; Millennium Ecosystem Assessment, 2005). Inland fisheries in Africa, however, remain of significant importance in terms of their potential to contribute to provision of employment, improved nutrition, poverty reduction, and food security (FAO, 1999a; FAO, 2009; UNEP, 2010). Africa contributed 25 % of the global inland fish catch of 10 million tons in 2008 (FAO, 2009; UNEP, 2010) and it is estimated that over 200 million Africans consume fish on a regular basis (Heck *et al*. 2007). Despite its high importance, most African countries lack essential statistics on the current status and potential contribution of fishery resources to livelihoods and food security (World Fish Centre, 2003).

The stress on tropical fresh water fisheries is worsened by the practice of illegal fishing and noncompliance with regulations, which has serious consequences in most of these regions. The

practice of illegal fishing, particularly the use of small mesh sizes in an already over-fished resource, will undoubtedly lead to stock collapse and fishery closure. It removes small fish before they can finish their life span and hence limits the opportunity for reproduction (Clark, 1990). This calls for urgent action to reduce noncompliance with fishery regulations, especially the use of small mesh sizes in these regions. Noncompliance with regulations on the continent also contributes to lack of accurate statistics about the status and potential role of fishery resources both at local and national levels (World Fish Centre, 2003). It is believed that the actual catch from inland water is 2-3 times larger than what is reported in official statistics due to illegal fishing and noncompliance with regulations, especially in the artisanal systems predominant in sub-Saharan Africa (SSA) (FA0, 2003; Welcomme *et al*. 2010). Failure to account for illegal fishing therefore gives incorrect estimates of the resource and misleads fishery policy formulation and management decisions based on this information (Hatcher and Pascoe, 2006, Atta-mills *et al*, 2004). Achieving compliance with fishery regulations is accordingly becoming an issue of serious concern to managers and policy makers worldwide and especially in the tropical freshwater fisheries of SSA.

Studies show that noncompliance with mesh size regulation is very common in Africa driven by the motive of maximising harvest from open access fishing waters and the difficulties associated with enforcing regulations, seriously affecting fishery resources on the continent (Akpalu, 2008a, 2009; Eggert and Lokina, 2010). Sudan is no exception and is experiencing the same pressures of stock declines and over-fishing as a result of noncompliance with mesh size regulation, especially in Jebel Aulia Reservoir (JAR) (FAO, 2008; FAO 1999b).

Although the fishery sector's contribution to national income in Sudan is small (i.e. 0.4 % of gross domestic product – GDP), fishing is the source of employment and livelihood for large communities (Ali, 2000 and FAO, 2008). It is estimated that the sector provides employment to more than 64 500 people, supplying more than 64 550 thousand tons of fish every year (based on 2006 FAO statistics), and 90 % of the estimated production potential of the country from inland waters (FAO, 2008). The inland waters of Sudan are populated with over 126 fish species in various localities in the country and the main inland fisheries are lakes and reservoirs (FAO, 1991; Hamid *et al*. 2009).

JAR is the main source of inland water of Sudan, inhabited by over 56 species, and is the major supplier of fresh and processed fish, contributing 23 % of the total inland catch (about 52 %, excluding the Sudd region) (FAO, 2008). Important consequences of noncompliance with mesh size regulations in JAR area include changes in fish biodiversity, as some species become rare or disappear. A decrease in sizes and length of the population of commercial species and fish production has been observed in this area (Fisheries Department, 2004; FAO, 1999b). A number of studies conducted in this area show that the size of *Alests spp. and Hydrocyns spp.* has decreased from over 15 and 30 cm to10 cm, in both cases. Furthermore, *Protopterus senegalus spp* appear only from time to time and *Citharinus scitharus spp* has not been seen for many years (Hamid, 2000; Fisheries Research Centre, 1985; Abusin, 2005). It is believed that fishers usually own two type of nets, illegal nets, which are used during active fishing breeding, and legal nets, used when catches of normal size are available (Hamid, 2000).

Over-exploitation by local inhabitants who are highly dependent on fishing and the use of destructive gear are believed to be the main causes of extreme over-fishing in the JAR area (FAO, 2008; Hamid, 2000 and FAO, 1999b). This indicates that prudent fishery management is of particular importance to the survival of fishing communities and the potential of fish consumption as an alternative high value animal protein in Sudan. Moreover, given current population growth rates of 2.5 % per annum (U.S. Census Bureau, 2011) and very high urbanisation patterns, it is expected that demand for fish will rapidly overtake current supplies, exacerbating the pressure on fisheries' ecosystems.

Other factors that are responsible for the pressure on the JAR area fishery are the lack of effective institutional structures, insufficient monitoring manpower and equipment in fisheries departments' enforcement sections and the little assistance received from other supporting agencies (e.g. the police and judiciary), making monitoring and enforcement of regulations too expensive (FAO, 1999b; Jebel Aulia Regulation Office, 2004). Tolerance of corruption and widespread poverty among fishers are also believed to be reasons for noncompliance with fishery regulations (FAO, 1999b). These factors are also confounded by the difficulties associated with modernisation and mechanisation of a largely subsistence fishery industry, still using primitive technology for fishing gear, preservation and curing methods (Ali, 2000). Reasons for this

pressure and opportunities for correction are currently poorly understood. However, noncompliance with fishery regulations is considered to be the key current challenge to sustainable fishing in the JAR.

A number of studies have been carried providing descriptive analyses of the fisheries of JAR (Adam, 1986; Fisheries Research Centre, 1985; FAO, 2008; Faisal, 2007; Khalid, 1994; Hamid, 2000; Fisheries Research Centre, 1985; Osman, 2009, Ali, 2000 and Hamid *et al*., 2009). These studies focus mainly on documenting and analysing fishing techniques, gear selectivity, and biological and ecological aspects of the fishery plus basic socio-economic analysis of fish as a source of nutrients and processed food. Lack of essential data and methodological deficiencies limit the value of current research to policy and management improvements. Some attempts have been made to estimate fish stocks in the JAR (Fisheries Research Centre, 1985; Marc and Khalid, 1998; Faisal, 2007; Khalid and Salih, 2006), giving a recent estimate of a stock size of 12 600 tons (Khalid *et al*., 2008). All these estimations were based on biological measurement methods. The gap in fisheries research in Sudan is particularly large when it comes to investigating the behaviour and reactions of fishers to regulations.

Good understanding of the motives for illegal fishing is necessary to help policy makers and managers design appropriate intervention measures that would improve effectiveness and efficiency of enforcement of regulations and ensures sustainability of the resource use. The present study intends to analyse causes of the problem of over-fishing in the JAR and identify reasons behind the failure of current management and policy regimes to promote sustainable management and exploitation of fishery in this reservoir. In pursuit of the above purpose, the intended research will attempt to adapt existing analytical frameworks and methodological approaches to study noncompliance with regulations. The adapted models will be empirically implemented to specifically investigate determinants of noncompliance with mesh size regulations in the JAR. Results of the study will provide useful policy information on the nature and extent of violation of mesh size regulation and identify the factors that influence violation rates. This is the first research effort investigating the causes and implications of illegal fishing and noncompliance with fishery regulations in Sudan in general and particularly in the JAR.

1.2 Objectives of the study

The overall objective of this study is to analyse current management problems in the JAR fishery, particularly illegal fishing and their local and national implications. Under this main goal, the study attempts to pursue the following specific objectives:

1. Extend the existing analytical framework of noncompliance with fishery regulations to allow studying implications of the following adjustments to the DDM:
   - Use of frequency rather than intensity of violation as a measure of violation rate
   - Modify the hazard rate to suit frequency of violation as a measurement of violation rate in DDM; and
2. Employ the adapted model to:
   - Investigate determinants of violation decision in JAR; and
   - Measure the extent of violation within artisanal violators
3. Identify potential policy intervention measures for sustainable management and exploitation of the JAR fishery.

1.3 Hypotheses

In pursuit of above objectives the study aims to test the following hypotheses:

1. Social influence, decreases the degree of violation in JAR
2. The majority of artisanal fishers in the JAR belong to the occasional violators group;
3. The higher the penalty (net seizure), the lower the violation to mesh size regulation
4. The higher the social discount rates, the higher the decision to violate and the higher the degree of violation among violators' groups

1.4 Approach of the study

To conduct the above described analyses, this study intends to adapt analytical approaches currently used to study noncompliance with fishery regulation, introducing two distinct extensions to the commonly used DDM. First, the study plans to adapt the DDM to use frequency rather than intensity of violation as a measurement of violation rate. This allows for differentiating fishers into group behaviour typologies, which improves the policy relevance of noncompliance analysis. Second, the study extends and modifies the standard DDM to allow for non-constant probability of detection in analysing determinants of noncompliance with fishery regulation. The adapted models are then used to analyse the determinants and intensity of noncompliance with mesh size regulation among artisanal fishers in the JAR of Sudan. The study employs an ordered Probit model to conduct empirical analysis of influences of various factors of relevance on fishers' decision to choose which category of violator groups to join. A zero-truncated negative binomial model also employeds to investigate the determinants of and measure the degree of violation among violators of mesh size regulation in the JAR. The specified models are implemented empirically to data from a survey of artisanal fishers in the study area.

1.5 Organisation of the thesis

The study is organised into six chapters. The next chapter provides background information on current policy and management systems of fisheries in Sudan and specifically the status of JAR fisheries including the problem of illegal fishing and noncompliance with mesh size regulations. Chapter 3 reviews relevant literature on approaches and methods for studying determinants of noncompliance with fishery regulations. The analytical framework and approach of the study are presented in Chapter 4. Chapter 5 employs the adapted models to conduct empirical analyses of the determinants and intensity of noncompliance with mesh size regulation in the JAR and describes sources of the survey data used to estimate model parameters for artisanal fishers in the study area. Chapter 6 concludes the study with a summary of results and implications for policy and future research.

CHAPTER TWO

FISH PRODUCTION, MANAGEMENT POLICIES AND FISHING PROBLEMS IN SUDAN

2.1 Introduction

Sudan has a total inland water surface of 13 million hectares, which amounts to 5 % of the country's total area. The River Nile and its tributaries comprise the main feature of Sudan's hydrology, with a number of man-made lakes covering a surface area of 3 000 km^2. Natural lakes and the swamps of the Sudd region cover a total flood area of over 80 000 km^2, of which about 8 000 km^2 are permanent swamps. Flooding during the August to October season contributes about 80 % of the overall Nile water flow (FAO, 1991). This inland water ecosystem is of very high economic and environmental significance for the welfare of current and future generations in the country providing many critical ecosystem services. Fish is one of those important ecosystem services that inland waters support.

Like in the rest of the developing world, fish consumption and the demand for fish in Sudanese diet has been on a steady rise over the past years. Inland fisheries contribute more than 88.3 % (based on 2006 statistics) of total fish catch in Sudan, which amounts to 57 000 tons per year (FAO, 2008). Though fish resources have significant potential and are considered important for food security and socio- economic development in Sudan, the fisheries sector is still dominated by small scale and subsistence production systems employing relatively traditional technology. Fishers are the poorest among the Sudanese and most lack alternative sources of livelihood making them intimately tied to this resource and their very survival is highly vulnerable to the health status of this ecosystem (FAO, 1999). The sector is expected to contribute to reduction of poverty in Sudan, a country with population estimated to stand at nearly 40 million people, with a current annual growth of about 2.5 %, but the fisheries of Sudan face many political and economic constraints (FAO, 2008).

This chapter is organised into four sections. The next section provides a brief overview of the status of inland fisheries production, fish consumption patterns in Sudan, and the related

management policies and regulation system. Section three takes a closer look at the study area of JAR fisheries and provides background information on fisheries production and fishing problems such as over-fishing and use of illegal fishing gear in the area. A summary concludes the chapter.

2.2 Fish production and consumption patterns in Sudan

Marine and fresh fish resources are considered important for food security and socio-economic development in Sudan. The country has a high potential for the development of aquaculture, given its rich biodiversity of fish and a favourable environment with many cultivable species, and its land and water resources (Khalid *et al*. 2008). Sudan fisheries play important role in the economy, employing over 12 900 full-time fishers in addition to 51 600 people supported by the secondary sector (FAO, 2008). Table (2.1) shows the total fish catch of Sudan distributed by sector.

Table 2.1: Sudan total fish production by sector in 2006

Fishery sub-sector	Total production tons/year
Marine	5 550
Inland	57 000
Aquaculture	2 000
Recreation	-
Total	64 550

Source: FAO (2008)

According to the FAO (2008), the southern Sudan Sudd region is capable of producing 75 000 tons of fish per year on a sustainable basis. However, reported fish landings don't exceed 32 000 tons per year. That means the Sudd region's potential is under-utilised. The current low catch is mainly attributed to conditions of civil war running over several decades and use of primitive harvesting.

Though the contribution of Sudan's fishery sector to GDP is marginal, amounting to only 0.4 %, fish is considered to be the main source of protein for poor and landless communities. The sector contribution to the overall agricultural GDP decreased from 1.4 % in the eighties to 1.3 % in the

nineties (WFP, 2006). Total fish catch in Sudan has increased over the past two decades reaching 64 550 tons in 2006 (Figure 2.1, Table 2.1).

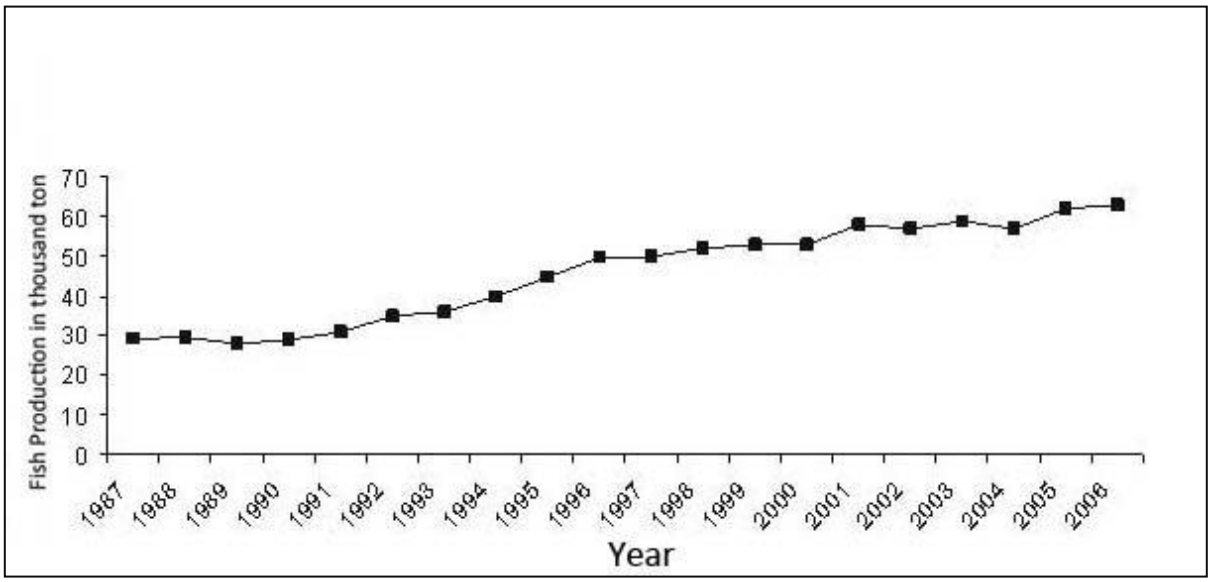

Figure2.1: Total fish production in Sudan in 000 tons from 1987–2008

Source: FAO (2006)

Sudan per capita fish consumption was estimated in 2008 at 1.6 kg per annum, which is considered low compared to other parts of the world (FAO, 2008). However, with current population growth rates of 2.5 per annum and very high urbanisation patterns, especially the influx to the capital city (Khartoum) region, it is expected that demand for fish will rapidly overtake current supplies, placing serious pressures on fisheries' ecosystems and hiking fish prices in the country. Fish consumption in Khartoum has increased markedly since 2005 when the influx of displaced people began (Figure 2.2). More than 70 % of the actual fish production is consumed fresh (basically caught from the White Nile-JAR and the upper southern reaches of the White Nile and the Sudd Region). Fish processing is very common (by salting, drying, fermenting and smoking) (FAO, 1999). Growth value of fisheries output reached US$ 1.2 billion in 2006 (FAO, 2008).

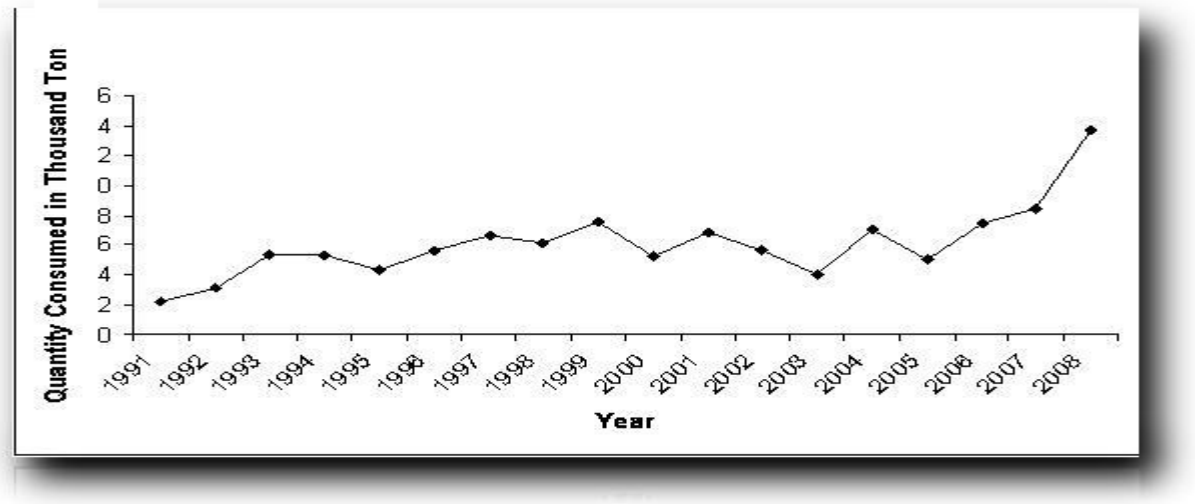

Figure 2.2: Quantities of fish consumed in Khartoum state, including production from both Khartoum and other states

Source: Adapted from Fisheries Department (MAAWR, 2006)

Inland fisheries contribute 88.3 % of the estimated production potential of Sudan. The main fishing localities are: the Sudd swamps in the south and the man-made lakes on the White Nile (JAR), the Blue Nile (Roseries and Sinnar Reservoirs), the Atbara River (Khashm El Girba Reservoir) and the main Nile River (Lake Nubia) (FAO, 2008). Most inland fisheries in Sudan are operated as small-scale artisanal systems. Different ethnic groups harvest these waters with relatively primitive equipment.

Over 126 species are observed in the fresh water fisheries of Sudan (Hamid *et al*. 2009). Nilotic and Falata[1] tribes use dugout canoes while Arab tribes use oar-propelled or motor-driven wooden and steel boats (Ali, 2000; FAO, 1999b). Although the inland fisheries of Sudan are in general poorly performing, a steady increase in market-oriented activities has occurred in recent years, particularly in the JAR area on the White Nile, which is the main source of processed fish, especially *fasiekh* [2] (FAO, 1999b). *Fasiekh* is the most popular fish food in Sudan and JAR has witnessed a large increase in the number of small industries supplying *Fasiekh* that is sold either wet or dried and distributed all over the country where local demand is very high. Due to the very high local market demand of *Fasiekh*, its price highly exceeds the price of fresh *Tilapia*.

[1] The Falata are an indigenous tribe of Sudan with a long-standing fishing tradition.
[2] *Fasiekh* (salted fish) is a popular food in Sudan.

Table 2.2: Sudan's *Fasiekh* exports (1985-1993)

Year	Export (metric tonnes)
1985/86	943
1986/87	800
1987/88	166
1988/89	690
1989/90	378
1990/91	244
1991/92	129
1992/93	39

Source: FAO (1999)

The country used to export large quantities of *Fasiekh* (95 % from JAR) to Egypt during the period of the seventies and eighties, but recently growth in local demand has led to a steady decline in surplus fish and fish products for export (Table 2.2). Another reason for the decrease is also the biological fact that the species that make up *Fasiekh* (*Hydrocyonus* and *Alestes)* are becoming small in quantities due to over-fishing (FAO 1999b).

Fish products other than *Fasiekh* that are consumed in Sudan include *Terkeen* (fermented fish), *Mandasha* (smoked and sun-dried), and *Seer*, a very small fried fish sold cheap. The home made *Terkeen* encourages the use of destructive gear, since the smaller the fish size the higher the market value of this product. The poultry industry is also obtaining undersized fish for preparation of chicken feed (FAO 1999b).

Fish imports from some African and Arab countries are reported to be growing. According to The Ministry of Agriculture, Animal Resources and Irrigation (MAARI), the amount of shrimp imported from Saudi Arabia, Egypt and United Arab Emirates (UAE) was 36 759 kg in 2006. This is in addition to 92 181 kg of inland fish (Nile perch) imported from both Uganda and Ethiopia in 2006 (Table 2.3) (FAO, 2008).

Table (2.3): Fish import through Khartoum market in 2006

Month	Product type and origin			
	Shrimps	Origin	Nile perch	Origin
January	550	UAE	2 500	Uganda
February	600	UAE/Saudi Arabia	10 100	Uganda/Ethiopia
March	-	-	1 065	Uganda/Ethiopia
April	505	Egypt/ UAE	7 500	Ethiopia
May	8 750	Egypt/Saudi Arabia/UAE	12 500	Uganda/Ethiopia
June	8 038	Egypt/ UAE	11 002	Ethiopia
July	8 326	Egypt/Saudi Arabia/UAE	17 704	Uganda
August	-	-	29 810	Uganda
Total	36 759		92 181	

Source: MAAWR (2006).

On the other hand, Sudan exports marine fish products. The main destinations for exports are Egypt, Saudi Arabia and Europe (Table 2.4). Cultured shrimps are exported to Saudi Arabia and the exported quantities were estimated for the years 2003 and 2004 to be 2 125 and 4 124 tons, respectively. Limited exports of shark to Asia are also reported (FAO, 2008).

Table 2.4: Sudan total fish exports during 2001-2006 in kg

Year	Fin fish	Trawl fish	Sardine	Sea cucumber	Shrimp	Trochus
2001	39 965	31	-	36 700	-	378
2002	70 250	358 895	1 614	44 920	39 46	367
2003	102 400	806 600	717	30 630	12 400	364
2004	153 210	973	1 638	19 000	71 120	336
2005	65 200	782	1 466	20 009	46 220	385
2006	37 700	-	-	9 750	-	341

Source: MAAWR (2006)

Table 2.5 gives the scientific and local names of Sudan's commercial fish species. Further details on contributions of each species to total catch and threats from over-fishing pressures in the JAR are presented in the following sections.

Table 2.5: Sudan's Commercial Species' Scientific and Local Names and Families

Scientific name	Family	Local names
Barbus bayad	Cyprinidae	Byad
Telapi zilli	Cichlidae	Bulty
Labeo niloticus	Cyprinidae	Dabes
Hydrocyonus forshalii	Characidae	Kass
Alestes dentex	Characidae	Kwara
Citharus citharus	Citharinidae	Bitkwya
Protopterus aethiopicus	Protopteridae	Umquro

Source: FAO (1999)

2.3 Fishery policies, administration and management systems in Sudan

The Fisheries administration in the Federal Ministry of Agriculture, Animal Wealth and Water Resources (MAA&WR) of Sudan is mandated to develop and enforce regulations all over the country. Fishing in Sudan in general is managed as a regulated, open-access resource; however, there is no limit to the size of the catch and no seasonal closure although some regulations have to be obeyed. Those include access licenses and a ban on destructive gear and small mesh sizes. Licensed fishers also receive subsidies to reduce fishing costs and help them overcome conditions of poverty (Fisheries Department, 2004).

Despite these regulations, illegal fishing practices such as use of undersized mesh nets (e.g. monofilament silk nets) is very common (FAO, 2008). The Fisheries Departments responsible for administering issuance of licenses and monitoring and control operations face major difficulties including the wide spread of a large number of fishers along the extensive banks of the White Nile and other river and lakes, which makes it hard to monitor these fishing activities. Lack of effective institutional structures to carry out mandated monitoring and control tasks, leads to poor enforcement of fishery regulations. Moreover, most fishers who harvest from inland waters lack alternative income-generating options**.** It also receives little support from other related institutions such as the police and the judiciary**.**

These difficulties in managing the resource encourage illegal fishing, especially the use of undersized meshes, which is spreading rapidly throughout the inland waters of Sudan. This has

become easily noticeable in the official markets as the numbers reported in Table 2.6 show quantities of fish caught illegally by using undersized mesh marketed in the different states of Sudan. The states of Kassala and Sinnar have the highest incidence of illegal fishing (in percentage) but the quantities caught (marketed) in these states are smaller than those caught in the White Nile state. Failure to control illegal fishing due to inability to enforce regulations is also attributed to poor definition and dissemination of regulations, which need to be updated regularly with new components (Jebel Aulia Regulation Office, 2004).

Seventy per cent of the fish is consumed fresh, some quantities are sun dried (25 %) or wet salted (5 %). Sun-dried fish is mostly marketed in rain fed and mechanized agricultural schemes (FAO, 2008). Wet-salted fish (mainly *Hydrocyonus* and *Alestes* spp.) is for local consumption or export and an insignificant amount goes into fish and poultry feed production. With the exception of some shrimp, all landings are of freshwater fish products (FAO, 1999b).

Table 2.6: Estimated Undersized and illegal Fishing marketed in Khartoum and other market destination in different States in 2005

State	Total prod Tons/year	% catch imported to Khartoum	Illegal fishing % of total catch
Gazera	750	7	2
Red sea	3 500	-	15
Blue Nile	595	80	2
Northern	2004	95	7
White Nile	65 00	70	17
Sinnar	850	3.5	27
Kassala	500	-	60
Khartoum	1 400	100	5

Source: MAAWR (2006)

Table 2.6 also gives information about amounts of fish marketed in Khartoum and other market destinations as a percentage of total production of different Sudanese states in 2005. A large difference is observed between the quantities that are traded in markets and estimates of total supply of fish reported earlier. This is attributed to a number of factors. First, a significant share of the catch is consumed at home given the subsistence nature of artisanal fisheries dominating

Sudan. Also, the Sudd region catches are not included in the figures reported in Table 2.6. Moreover, some fish quantities are used for animal feed and other purposes. In general, the fishery sector of Sudan is characterised by limited supply and high prices.

Other important factors behind the poor performance of Sudan fishery sector are the lack of effective coordination mechanisms among the institutions responsible for fisheries management and overlapping duties (Hamid *et al*., 2009). Sudan laws and acts for environmental management (fishery, forestry, water and wild life) are implemented and monitored on a sectoral basis that operates in a fragmented and uncoordinated manner, resulting in government institutions working in isolation from each other. The Higher Council for Environment and Natural Resources (HCENR), established in 1990, is mandated to coordinate implementation of these sectoral environmental management laws and policies but has been ineffective and unsuccessful in achieving its objectives (Hamid *et al.* 2009).

2.4 Status of the fishery and problem of illegal fishing in Jebel Aulia Reservoir

The JAR on the White Nile extends over 629 km south of the Jebel Aulia dam (JAD) upwards to Renk city, south of Kosti (see Figure 2.3). The White Nile extends 600 miles from Lake No in the south to Khartoum in the north. This reservoir is at present used for irrigation purposes and its water level decreases from February until May and reaches its highest level in September.this reservoir is believed to be endowed by ecological factors that create favourable environment for species to regenerate. These ecological factors are described by FAO report in 1999 as follows:

"In the area of Jebel Aulia reservoir zooplankton is characterised by a considerable diversity of forms and a high biomass quantity especially in the pre-dam area. Decrease in current velocity, reduction in the quantity of suspended substances and development of submerged vegetation are all favourable conditions for the development of plankton organisms in this lacustrine."

The reservoir is the main supplier of fresh and processed fish in Sudan, contributing 52 % of the total inland catch (excluding Sudd region in the south) (FA0, 2008). It is the largest second source of fish in Sudan after the Sudd region in southern Sudan (see Table 2.7). The location of

the JAR near the capital city Khartoum gives it an economic advantage. The reservoir is endowed with over 56 fish species from 13 families. Fish in this reservoir are characterised by varied spawning seasons. For instance *Barbus binny*, *Hydrocyonus* spp. and *Alestes* spp. spawn during March–April (late winter) while *Lates niloticus* has a prolonged spawning period and other fish species spawn in (autumn) July–August (FAO, 2008).

Since construction of the JAR dam was completed in 1933, people began to settle in the area surrounding the dam. The JAR population is comprised of local fishermen living along the banks of the river. Small fish markets exist on a site next to the dam where transactions are made by middlemen and fish are transported to consumption areas by trucks using ice for preservation. Fishers land their catches on scattered beaches and normally in small quantities and fish traders (mongers) provide informal credit to fishers to support their families especially during seasons of limited catch and finance most of the marketing activities.

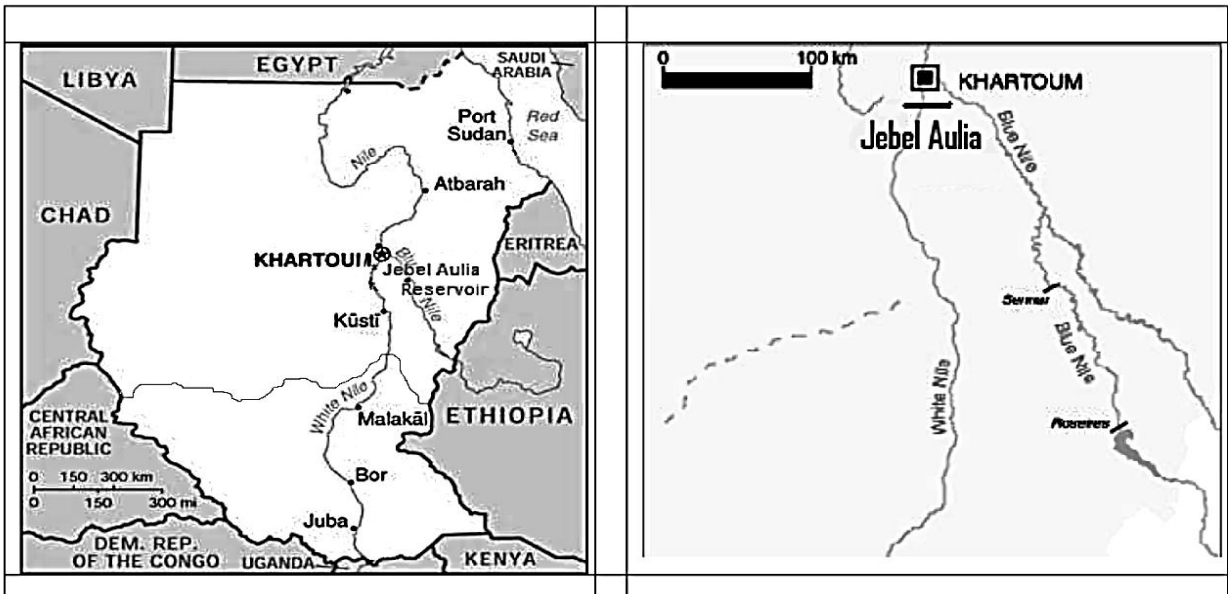

Figure 2.3 Map of Sudan showing the location of Jebel Aulia Reservoir on the White Nile

Source: Adapted from FAO (2008) and UNEP (2000)

The JAR witnessed a remarkable increase in population in the settlement camps as a result of displaced communities from southern Sudan because of the civil war (International Organization for Migration, 2005). This caused the emergence of major markets and triggered significant socio-economic changes related to food**.** For instance, the market for small-sized fish grew

significantly and new types of products such as *Mandasha*[3] were introduced. The demand for small-sized fish rose because it was the basic food for displaced communities (Abusin, 2005). Some illegal undersized catches are processed at home to produce food that is cheap, easy to prepare and easily stored. The species used for home processing are *Hydrocyonus forkhali*, *Alestes dentex*, *Alestes nurse*, and *Labeo niloticus.* These are the species that currently threatened by over-fishing and their local names are *kass*, *kawara* and *dabis*, respectively (Abusin, 2005).

Table 2.7: Inland fish harvests in 2006 in Sudan by sources

Production source		Yield in tons
Sudd swamps, lakes and backwaters		32 000
Manmade lakes	Jebel Aulia Reservoir	13 000
	Roseries Reservoir	1 600
	Sinnar Reservoir	1 100
	Khashm El Girba Reservoir	800
	Lake Nubia	2 000
Dinder, Rahad Rivers and other River Nile tributaries		4 500
Impoundments and irrigation canals		2 000
Inland fishing total		57 000

Source: FAO (2008)

Fishers are increasingly setting their nets very close to the dam wall, inviting serious complaints from the Ministry of Irrigation for fear that these nets might negatively affect the proper operation of the evacuation sluices (FAO, 1999b).

The northern part of JAR has four regulation stations located in two different states: one is in Khartoum at Jebel Aulia station and three are in the White Nile state. These stations are understaffed and specialised fishery competencies are absent from them (FAO, 1999b). As in all Sudan fisheries, JAR is regulated as an open access regime. Fisheries Administration in the MAA&WR, based in Khartoum state, is in charge of enforcing regulations and monitoring violations through its regulation office at JAR next to the dam site.

[3]Mandasha is smoked fish, shaped into small balls and sundried, then stored and used in farming camps and is very popular in southern Sudan.

The Fisheries Department of the MAA&WR recommends a mesh size of 100 mm. However some of the commonly used gillnets in the region have mesh sizes ranging from 60 to 160 mm especially designed for catching Tilapia (*Oreochromis* spp.). Another type of gillnet known as the Bee-Bee has mesh sizes ranging from 30 to 40 mm. These are over 100–500 m long and can be 1.5 to 2 m deep (FAO, 1999b). They are used at night in open waters, targeting small species such as *kawara* and *kass* (Tables 2.8 and 2.9), which are mainly used to make the popular *fasiekh* food. Beach seines are another type of gillnet that is either made to a length of 500 m (*umsura*) or as large-sized beach seines (*umkubuk*) consisting of nets with a large mesh size hanging in the middle and smaller meshes along the aisles. To increase the catch, fishers often spread sorghum grain (*durra*) as bait along the targeted shoreline two to three hours before the actual operation (FAO, 1999b).

Despite JAR fishing regulations, fishers are reported to violate regulations especially by using small mesh size (Jebel Aulia Regulation Office, 2004). A study conducted by Fisheries Research Centre (1985) in the northern part of JAR revealed that half of the fish catch was made up of undersize fish (Table 2.8). The differences in sizes (measured by length) between fish caught illegally and prescribed sizes are clearly large. Since 1985, the situation has worsened and over-fishing has been cited as the main cause of the undersized catch. Many factors are reported to be the reasons behind over-fishing in JAR. Among these reasons are the increased use of illegal fishing gear, such as mesh below prescribe size, deficiencies in law enforcement, loss of species diversity, heavy fishing pressure on the remaining breeding grounds and reduction of natural regeneration (FAO, 1999b).

Table 2.8 shows results of a survey conducted in the area where the size of commercial species caught was measured. The difference between caught and prescribed sizes is very large and hence a matter of serious concern. Fish above first maturity age were scarcely found in the experimental and commercial catches (FAO, 1999b). This suggests that noncompliance with prescribed mesh size is clearly a major issue in the northern part of JAR.

More than 56 fish species are found in JAR, from which the endangered species *kass* and *kawara* are processed as wet and salted fish. The other commercially important fish species in JAR are

shilbya, *dabis* and *bulty* (Table 2.9). The first four species in Table 2.9 are mostly used for making fish products, while others are sold fresh (FAO, 1999b).

Table 2.8: Prescribed and actual length of species' size in 2004 (average)

Targeted species	Prescribed species sizes in (cm)	Actual fish length (cm)
Bayad	55	31
Bulty	20	8
Dabis	45	17
Kass	30	20
Kawara	20	10

Source: MAAWR (1997)

Table 2.9: White Nile catches composition of selected commercial species in JAR, 1986

Scientific name	Local names	% of total catch
Hydrocyonus forkhali	Kass	10
Chrysichthys auratus	abuRial	5.2
Labeo horie	Dabis	5
Alestes dentex	Kawara	4.8
Eutropius niloticus	Shilbya	4.6
Telapia zillei-oreochronus	Bulty	4.6
Hydrocyonus lineatus	Kass	4.4

Source: Rahaman (1985)

JAR fishers use canoes for catching fish and two types of boats are common in the area: *sharook* and *moorkab*. Both have a life expectancy of 8 to 10 years. The maximum capacity of the *sharook* is two nets and it is usually fitted with an outboard engine. These canoes are usually used in the southern part of JAR. The *moorkab* is 4 to 6 metres long and not motorised, with a maximum capacity of five men and five nets. Canoes made from local wood (*Acacia nilotica*) are common in the northern part of the reservoir. Canoe motorisation levels are rather low among *moorkabs*. A 500-metre net lands a catch of 100-150kg in JAR, while that from a 100-metre net ranges from 50 to 60 kg (FAO, 1999b).

Fishing seasonality is very important to explain for two reasons first, JAR fish species are characterised by varied spawning seasons (late winter and autumn). Second, it identifies which type of gear fishers will use to get a catch. For instance, in JAR there are three different seasons. The first extends from November to February and considered to be the main fishing season when mature fish is relatively abundant. The second season extends from March to July when fishes are rare and fishers tend to use illegal nets. The third season coincides with the rain and flood season, when some fishers shift to agriculture, some continue fishing in a very hard situation and others stop fishing altogether (FAO, 1999b).

As seen above illegal fishing and over-fishing are clearly the main source of pressure on the fishery of the JAR. Unfortunately, apart from isolated reports on inland fish catch and their value in Sudan, reliable information on status of the fishery hardly exists. Illegal fishing, especially catches of smaller than prescribed size, is very common as fishers, who are mostly poor, are interested more in bigger catches for survival than commercially desirable fish size. Local inhabitants as well as fishing companies are both involved in over-fishing in the White Nile area. Companies and fish brokers transport fish to the marketing areas in insulated trucks or chilled ice boxes (FAO, 1999b). Gillnets are the most dominant gear in this region because they are certain to catch all the fish behind the gill cover (FAO, 2000). The probability of capture or escape from the net after contact depends totally on the fish size, which is why size selectivity is distinctive for gill nets (Potter and Pawson, 1991). The use of silk is particularly dangerous (very thin and sharp) because it kills all enmeshed creatures and has especial large catch capacity because it is invisible and it is therefore highly deceptive (Osman, 2009). Use of gillnets made from monofilament (silk) thread, unlicensed fishing and fishing during reproductive seasons are reported to be common violations in the JAR area (Fisheries Department, 2004).

The use of illegal techniques, such as undersize gillnets to catch immature fish (i.e. catching species for fish processing of 20 mm instead of 40 mm or commercial species under 100 mm), is considered the main source of the fishing pressure in JAR (Jebel Aulia Regulation Office, 2004). Food processing in the area is also becoming a good business, which adds a financial incentive that increases the existing tension between production and enforcement agencies, which are under-resourced, and this result in continuous, routine violation. The fact that many fishers wish

to migrate from the area, arguing that it is difficult for them to find an easy catch due to the large number of fishers is one good indicator of over-fishing pressure (Jebel Aulia Regulation Office, 2004).

It is clear that serious efforts and significant investments in generating better information and research on the status of the fishery and good understanding of fishers' behaviour towards regulation are badly needed to improve the management of the JAR fish resources. Fisheries Departments clearly require major investments to upgrade their financial and human resource capacities for more effective monitoring and enforcement. It is necessary for all that to conduct more comprehensive and in depth scientific investigation and analysis of fishery crime and its economic, social and political determinants. The purpose of this research is therefore to contribute to this need.

2.5 Summary

About 5 % of the total area of Sudan is covered by water and the fresh water fishery is an important resource for the country and its people, especially the landless poor. Fresh waters resources of Sudan are characterised by rich biodiversity of fish, which is a valuable food source with high protein content and calorific value. It also offers employment to many who depend totally on fishing for their livelihoods. Sudan also has good prospects for prosperous development of aquaculture.

About 88.3 % of the total fish production is from inland waters, of which 70 % is consumed fresh. Generally, the fishery sector in Sudan is characterised by its traditional technology and poor performance attributed to many factors such as weak enforcement of fishery regulations, lack of effective institutional structures and the little support from other law enforcement and natural resource management institutions. As a consequence of these difficulties in managing the resource, illegal fishing practices are spreading, placing serious pressure on an already over-fished resource, especially in recent years.

JAR (White Nile state) is the main supplier of fresh and processed fish. The most common gear used for fishing are gillnets, and non-motorised *moorkab* canoes are common in the northern part of the reservoir. The larger segment of the population in JAR is poor, comprised of local landless fishermen with limited income and employment opportunities other than fishing. Apart from the main fish market in Khartoum, some small fish markets exist on site next to the dam and transactions are carried through middlemen.

The excessive population of fishers at this reservoir leads to over-fishing, which directly affects species biodiversity and reduces their sizes. Fishers cope with this by reducing mesh net sizes and hence confounding pressure on the fishery particularly in the northern part of JAR. Other factors such as deficiencies in law enforcement, heavy fishing pressure in the reproduction season and reduced natural regeneration are also causes of the pressure. Illegal fishing especially use of small mesh size is therefore considered the main challenge facing this important fishery resource.

The JAR Regulation Unit lacks resources and specialised personnel. Failure to control illegal fishing due to inability to enforce regulations is also attributed to lack of proper means, deficiencies in formulating rules, and costly and weak enforcement and monitoring of compliance with laws and regulations.

The present study intends to analyse causes of the problem of noncompliance with mesh size regulations in the north of JAR and identify reasons behind the failure of current management and policy regimes to promote sustainable management and exploitation of fishery in this reservoir.