# ASSESSMENT OF THE EFFECTS OF PESTICIDES USED ON FLORICULTURAL FARMS ON WATER QUALITY AND WATER BIRD NUMBERS IN LAKE NAIVASHA, KENYA

By

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# ABSTRACT

Lake Naivasha and its environs experienced increased levels of pesticide application due to the direct flow of agrochemicals pollution into water bodies from rapid expanding floricultural farms. The situation had recently raised speculation having attracted public attention following thousands of fish deaths earlier reported. The Lake is under threat of losing its water birds a phenomenon linked to water quality degradation. However, there is no specific research which has been done on the effects of pesticide residue on water physico-chemical parameters and water bird numbers within the shores of Lake Naivasha. The Organochlorine pesticide residues previously detected is persistent in the environment and bio-accumulates in the body tissue of water birds while, the Organophosphate pesticides which had been adopted as an alternative to Organochlorine pesticides are highly toxic to water birds. The occurrences of pesticide residue in water provide a dietary pathway to the aquatic ecosystem which contributes to reduction of water bird numbers. The study investigated the effects of Organochlorine and Organophosphate pesticide residues on water quality and how they affect water bird numbers. The specific objectives of the study were: to determine water physico-chemical parameters, to determine the concentration of Organophosphate and Organochlorine pesticides and lastly, investigate the effects of water quality on water bird numbers within the shores of Lake Naivasha. Longitudinal study design was adopted between February to July, 2011 (6 months). The sampling sites were selected on the basis of their relevance as point sources of pesticide contamination and uniqueness in the nature of discharge released into the Lake. Three replicates of water samples were collected giving 18 water samples per site, totalling to 90 samples. These samples were subjected to water quality analysis and Gas Liquid Chromatography technique while, the ecological study of water birds focussed on their numbers. The study targeted bird's beak since this feature was conspicuous while the counts were based on standardised belt transects method. The data generated were recorded on Microsoft excel spread sheets and subjected to analysis while applying Statistical Package of Social Science using one way ANOVA at $p<0.05$. The results revealed that the water samples tested were in compliance with World Health Organisation and Kenya Bureau of Standards recommended guidelines in regard to physico-chemical parameters standards while, Organochlorine and Organophosphate pesticide residues were not detected. The results also revealed an increase in the water bird abundance. It was concluded that lack of these pesticide residues and an increase in water bird abundance was due the current conservation measures preventing water pollution in the Lake. The study further, recommended continuous monitoring and conservation measures to be maintained.

# CHAPTER ONE

# 1.0 INTRODUCTION

## 1.1 Background to the Study

Floricultural farming was established in Lake Naivasha and its vicinity in the early 1980's and currently it is occupying more than 4,000 hectares (Becht *et al*., 2006). The expansion of this sector has changed the ecology of Lake (Harper and Muchiri, 1986). This monoculture practice is associated with consumption of a lot of water and pesticides. Following this, Lake has experienced increasing levels of agrochemical pollution contributing to its water quality degradation. This has been accelerated by the greenhouses where flowers are grown as they use pesticides on a continuous basis to facilitate high productivity (IPCS, 2005). These pesticides have significant effect on the environment since over 98 percent of sprayed insecticides and 95 percent of herbicides reach destination other than the target namely: air, water, bottom sediments and food (Miller, 1998). Wind and rain carries away pesticides from their point source, causing contamination of surface waters (Bouman *et al.,* 2002 and Shomar *et al.,* 2005).

Floricultural farms have extended their boundaries right down to the water bodies (Arusei *et al.,* 2002). This makes it easier for waste discharge containing pesticides to be washed into the Lake without any treatment. Incidences of pesticides from flower farms reaching the Lake have increased (New Vision 11th Nov, 2003). The increasing levels of pollution in the Lake contributes to water quality degradation yet there has been no specific research done to determine the effects of these pesticide residues on water physico-chemical parameters within the shores of Lake Naivasha. Furthermore, most grounds have been left bare as natural vegetations are cleared to create more space for the expanding floricultural sector. This accelerates soil erosion especially for the alluvial and loamy soil types found in the region (Arusei *et al.*, 2002) which are characterized by fineness in texture, high water retaining ability and high levels of soil organic content accelerate drifting of pesticides as soils are eroded (Kellog *et al.,* 2000; Becht *et al.,* 2005). These soil sediments adsorbed with chemicals are carried into water bodies and eventually into the Lake.

Detectable levels of pesticide residues have been reported earlier in inland waters in Kenya (Mugacia *et al.*, 1992 Wandiga, 2001; Gitahi *et al.*, 2002; Getanga *et al.*, 2004). Organochlorine and Organophosphate pesticides are still in common use in the Lake's vicinity (Jolicoeur, 2000; Janeth, 2001 and Gitahi *et al.*, 2002). For instance, Lindane, Aldrin, and Dieldrin are used for seed dressing while Dichlorodiphenyl-trichloroethene in public health especially for fight against Malaria (Thumbi *et al.*, 2000). These pesticides are hazardous yet there has been no recent research done to determine their pesticide residue levels in water of Lake Naivasha. Moreover, water is a dietary pathway through which these pesticides get into body tissues of aquatic organisms.

Farmers still prefer to use OC and OP pesticides due to their effectiveness in pest control and wide use on variety of crops (USEPA, 2007; Wandiga, 1995).Their use is deemed inevitable despite their ban or restriction (Thumbi *et al.*, 2000). Once these pesticides have been applied in the fields, they are transported to the Lake by surface runoff, rivers and streams (Wandiga, 2001; Wandiga *et al.,* 2002; Getanga *et al.,* 2004). Moreover, they have been applied following inappropriate recommendations (Lalah, 2001). The Pest Control Product Board has noted a number of malpractices especially at the user level (PCPB, 1998).

Organochlorine pesticide residues in aquatic environment have lead to widespread concern over environment and human health issues (Smith *et al.,* 1994). They have low chemical and biological degradation rates leading to their accumulation in biological tissues and subsequent magnification in organisms progressing up the food chain (Mugacia *et al*., 1992; Wandiga 2001; Gitahi *et al*., 2002; Mavura and Wangila, 2004). Moreover, Organophosphate pesticides are highly toxic to vertebrates (UNEP, 2003). Such effects may cause loss of ecological biodiversity (Harper *et al.,* 1990).The declining water bird numbers could be as a result these effects yet there has been no specific research to investigate these effects on water birds within the shores of Lake Naivasha. However, there are always speculations which lacks scientific backing whenever incidences occur in the Lake for instance, the recently thousands of fish deaths reported on the southern shorelines where the floricultural farms are located raised concerns having attracted public attention. Consumption of fish from contaminated water bodies is considered to be an important route of exposure (Mavura and Wangila, 2004; Mwevura *et al*., 2002). The water birds prey on fish yet there has been no further investigation to find out the extent to which this could have affected the water birds. The Lake is under increased threat of losing its water birds especially, Fulita cristata, Haliacetus volifer and Prionops poliolophus which prey on fish (CGIAR, 2010).

Once these pesticides find their way into the bird's tissues where they influence physiological and metabolic processes leading to reproductive failure, egg shell thinning and breeding failure, egg hatchability and low survival rates of chicks (Spitzer *et al.*, 1978, Grier, 1982; Cade *et al.*, 1971; Nisbet, 1975). The reduction in water bird numbers in the Lake was an indication of underlying environmental problems (Bennun *et al.*, 2002) as such phenomenon are linked to water quality degradation. However, there has been no specific research which has been done in Lake Naivasha to investigate these effects on water birds.

The capacity to analyse for trace amounts of pesticides (pesticide residue analysis) remains a challenge to most African countries (Mavura and Wangila, 2004). This is due to ill equipped laboratories. For instance, in Kenya, data on pesticide residue levels in areas where they are heavily used is still limited (Barasa, 2007). This means that research based decision making has not been adopted fully in our country According to an assessment carried out by Inter-governmental panel on climate change (IPCC, 2005) it is an uphill task for many ecosystems to recover from environmental damage Therefore, this study has provided important information which is vital for effective policy making and implementation.

**1.2 Statement of the problem**

Lake Naivasha has experienced an increase in anthropogenic activities associated with the expanding floricultural sector. This sector is associated with consumption of a lot of water and pesticides. The resultant effect of these activities is the increasing levels of agrochemical pollution in the Lake. These pesticides have significant effect in the environment since over 98 percent of sprayed insecticides and 95 percent of herbicides reach destination other than the target namely: air, water, bottom sediments and food (Miller, 1998). Wind and rain carries away pesticides from their point source, causing contamination of surface waters (Bouman *et al.,* 2002 and Shomar *et al.,* 2005) contributing to water quality degradation.

Organochlorine and Organophosphate pesticides are still in common use in the Lake's vicinity (Jolicoeur, 2000; Janeth, 2001 and Gitahi *et al*., 2002). Once these pesticides have been applied in the fields, they are transported to the Lake by surface runoff, rivers and streams (Wandiga, 2001; Wandiga *et al.,* 2002; Getanga *et al.,* 2004). Furthermore, the alluvial and loamy soil types found in the region (Arusei *et al.*, 2002) are characterized by fineness in texture, high water retaining ability and high levels of soil organic content accelerate drifting of pesticides as soils are eroded (Kellog *et al.,* 2000; Becht *et al.,* 2005). These are known to facilitate erosion of soil sediments adsorbed with chemicals into water bodies and eventually into the Lake causing water degradation. Pesticide residues contribute to water quality degradation yet there has been no specific research done to determine their effects on water physico-chemical parameters within the shores of Lake Naivasha.

Organochlorine pesticide residues in aquatic environment have lead to widespread concern over environment and human health issues (Smith *et al.,* 1994). Furthermore, water is a dietary pathway through which these pesticides get into body tissues of aquatic organisms. For instance, Organochlorine pesticides have low chemical and biological degradation rates leading to their accumulation in biological tissues and subsequent magnification in organisms progressing up the food chain (Mugacia *et al*., 1992; Wandiga 2001; Gitahi *et al*., 2002; Mavura and Wangila, 2004). Moreover, Organophosphate pesticides are highly toxic to vertebrates (UNEP, 2003). Such effects may cause loss of ecological biodiversity (Harper *et al.,* 1990). The reduction in water bird numbers in the Lake was an indication of underlying environmental problems (Bennun *et al*:, 2002) However, there has always been speculations without scientific backing whenever incidences occur in the Lake for instance, the recently deaths of thousands of fish reported on the southern shorelines where the floricultural farms are located raised concerns having attracted public attention. The deaths of fish meant that the Lake was under increased threat of losing its water birds especially, Fulita cristata, Haliacetus volifer and Prionops poliolophus which prey on fish (CGIAR, 2010) yet there has been no further investigation on this regard.

Once these pesticides find their way into the bird's tissues where they influence physiological and metabolic processes leading to reproductive failure, egg shell thinning and breeding failure, egg hatchability and low survival rates of chicks (Spitzer *et al*., 1978, Grier, 1982; Cade *et al*., 1971; Nisbet, 1975).

### 1.3 Objective of the study

The broad objective of this study was to assess the effect of pesticide residues from the flower farms on water quality and the water bird abundance on the shores of Lake Naivasha, Kenya.

**Specific objectives were:**

i) To determine the physico-chemical parameters viz. Temperature, Conductivity, pH, Turbidity, Dissolved Oxygen, Chemical Oxygen Demand, Biochemical Oxygen Demand and Total Suspended Solids in the water of Lake Naivasha.

ii) To determine the concentration of five Organophosphate pesticides namely: Nemacur; Orthene; Durban; Diazol; Fenitrothion; and five Organochlorine pesticides namely:

Endosulfan; Lindane; Aldrin; Dieldrin; Dichlorodiphenyl-trichloroethene in the water of Lake Naivasha.

iii) To investigate the effects of water quality on water bird abundance within the shores of Lake Naivasha.

## 1.4 Research hypotheses

i) The water physico-chemical quality attributes do not only deteriorate with increase in the level of pesticide residues, but also other residues entering the Lake environment.

ii) The strength of pesticide residues contamination is linked to the nature of pesticides in the discharge flowing into Lake Naivasha.

iii) The abundance and distribution of the water bird is affected by the quality of water within the shores of Lake Naivasha.

## 1.5 Justification of the Study

Kenya's annual per capita renewable water resource is less than the convectional universal minimum of 1000 cubic metre (GOK, 2010). Therefore, it is necessary to protect our fresh water bodies yet there has been no recent research on water physico-chemical parameters in the Lake. The Lake has undergone significant water degradation contributed by unsustainable agricultural practices associated with tremendous growth in floricultural sector in the last two decades. Therefore, urgent intervention is needed to put a stop to the ongoing agrochemicals pollution of the Lake. The extent of agrochemical pollution can only be ascertained through ongoing research which this study provided.

Lake Naivasha and its vicinity is the hub of floriculture accounting for 80 percent of Kenya's horticulture thus, an important area for cut flower in the country (Jolicoeur, 2000). This vibrant sector is producing flowers for export (Abiya, 1996). However, the climatic conditions in the Lake and its vicinity favour proliferation of pests and diseases. Therefore, farmers are bound to use all the available methods including pesticide to maintain their yield (IPCS, 2005). Furthermore, pesticides are preferred due to their convenience and effectiveness in pest eradication but prone to misuse. These pesticides are hazardous yet there has been no recent research done to determine pesticide residue levels in water of Lake Naivasha

Currently, export market is at stake for high trace levels of pesticide on fresh farm produce for export. This follows new compliance standards in line with the periodic review of maximum pesticide residue levels by the international trade organisation. These pesticide residue limits are adjusted accordingly based on specific interests which might be to the farmers' disadvantage. For instance, increasing sample size for pesticide residue analysis from 1 to 10 percent of all fresh farm produce for export yet most African countries do not have the capacity (Mavura and Wangila, 2004) due to ill equipped laboratories. In Kenya for instance, data on pesticide residue levels in areas where they are heavily used is still limited (Barasa, 2007). This challenge puts export market in a state of uncertainty unless we move with times and adopt a research based policies and decision making process. Thus these findings will play a major role in achieving research based policy making and implementation.

The data generated from this research forms useful data which will guide policy making and implementation bodies such as Kenya Plant Health Inspectorate Services, Kenya Horticultural Development Authority and Kenya National Environmental Council. These organisations are responsible for the regulations of the use of pesticides in the agricultural and health sectors.

There role is to help farmers to realise quality produce within the limits of pesticide residue levels and protect export markets by planning appropriate mitigation measures to combat the rising pollutant load in Lake Naivasha.

Lake Naivasha and its vicinity is an economic hub for the country thus, the region deserves protection so as to ensure a balance between its long term conservation and its exploitation for present social-economic benefits. The country earns millions of foreign exchange from flower export (NEMA, 2010; Harper, 2004). The sector also provides employment opportunities and income to a large population of Kenyan. Thus, loss of export market might be a big set back to our national economic growth. Furthermore, the Lake's catchment provides a number of essential natural services such as food regulation, soil fertility, carbon storage, regulation of climate, disease prevention and water purification (UNEP, 2006).

The Lake is an internationally recognized Ramsar site (RWC, 2010) and an Important Bird Area (Bennun and Njoroge, 1999). Freshness of its water enables it to supports rich biodiversity including birds (Harper et al., 1990) and it serves as an important stop point for water birds. Many birds have been recorded in the site over the years and it is estimated to be 350 bird species of which 90 are aquatic or semi aquatic (Bennum et al., 2002). Bird watching activities attracts foreign tourist from which foreign exchange is generated. These birds may face extinction if drastic conservation measures are not put in place.

The situation in the Lake is delicate and deserves attention prompting public interest. Following this, the government has established legislative framework for instance EMCA (Water Quality

Regulations, 2006) which provide important guidelines on water quality standards. There is need to replicate similar research in the further and reinforce continuous monitoring programs as suggested by Mavuti and Harper (2005) to enable identification with confidence the principal point source of Organochlorine and Organophosphate pesticide and put in measures to maintain their levels below the maximum acceptable levels in drinking water (WHO, 1984; CCME, 1991; GOK, 2006).

### 1.6 Scope and Limitation of Study

The study focused on the effects of Organochlorine and Organophosphate pesticide on water quality and water bird numbers. The study which lasted 6-months was initiated in February and completed in July, 2011. The map of the study area was carefully sketched and sites located by GPS. This study duration was sufficient to capture season variations. The study was based on laboratory and ecology investigations. Most of the point sources were traced with certainty. However, the papyrus fringes around the Lake made it difficult to assess some sites. The survey on water bird numbers gave a good indication of the ecological status of the Lake. However, there were few cases where the secretive ones remained hidden amongst papyrus making it difficult to estimate their numbers.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Introduction

This section gives a brief analysis of existing information which is relevant to the topic under study and also seeks to identify gaps in knowledge that need attention or further research. Water quality aspects based on current state of Lake Naivasha, determination of water quality by use of physico-chemical parameters, occurence and effect of Organochlorine and Organophosphate pesticide residue on water quality and water bird numbers. This section is concluded by the diagrammatic representation of the conceptual framework (Figure 2.1).

### 2.2 The Water physico-chemical parameters in Lake Naivasha

Lake Naivasha is the only fresh water lake in Rift valley. It was imperative to note that the basic water character of Lake Naivasha and other neighbouring lakes in Rift valley were compared in terms of selected water physico-chemical variables namely: conductivity and pH. Lake Baringo's conductivity range was 221-2110 µS cm-1; Lake Nakuru's conductivity range was 27185-48455 µS cm-1, (Shivoga, 1999; 2001) ; Lake Bogoria's conductivity range was 72000 µS cm-1 (Melack, 1981); Lake Baringo's pH range was 6.11-10.00 and Lake Nakuru's pH range was 9.21-10.60 (Shivoga, 1999; 2001) while Lake Naivasha's conductivity range was 233-480 µS cm-1 and pH range of 7.7-8.5. (Harper *et al.,* 1990). This freshness in the Lake's character supports diverse roles including: domestic purposes, energy generation, agricultural development, industrial growth, livestock and tourism development (State of Environment Report Kenya, 2006/7).

Kenya receives an annual average rainfall of 630mm which is relatively low for an equatorial country (FAO, 2005). Kenya's annual per capita renewable water resource is less than the convectional universal minimum of 1000 cubic metre (GOK, 2010). Thus, it is categorized as a water scarce country based on the average per capita water availability (WRI, 2007). Safe drinking water is as a basic human need, yet many Kenyan do not have access to adequate and safe water supply. This makes it necessary to protect our water bodies against all forms of pollution or over abstraction. In the recent years the Lake has undergone significant ecological changes leading its classification as a RAMSAR site requiring urgent attention to save it from extinction. Public interest has prompted establishment of Environmental Management and Coordination Act on Water Quality Regulations, 2006 to provide important guidelines on water quality standards.

Globally, it had been estimated that anthropogenic demand for water had led to 50% loss in wetlands habitats in the last century (Duggan, 1990). Harper *et al.*, (1995) pointed out that water withdrawals had significant effect on the Lake's water level as it leads to higher concentration of pollutants in the Lake leading to environmental degradation. Furthermore, the Lake experiences high mean annual evapo-transpiration rate which is far much above the average annual rainfall (Harper *et al.,* 2002).

The horticultural sector in the Lake's environs has generated other ecological problems, including water abstraction leading to reduced water levels (Becht and Harper, 2002; Njuguna, 2005). This pressure has necessitated Lake Naivasha Riparian Association to influence its members to install water meters and adopt less wasteful irrigation (Watson, 2010). Furthermore, prompting the establishment of legislative process for sustainable development and to create a balance between its long term conservation and exploitation for present social-economic benefits.

### 2.3. Water Quality aspects by use of physico-chemical parameters

#### 2.3.1 Water Temperature

The surface water temperatures of Lake Naivasha were on the rise (Campbell *et al.*, 2003). This is a function on depth, season, time of the day, cloudiness of the sky and the air temperature (Webster and Benfield, 1986). However, suspended and dissolved solids arising from anthropogenic activities also influence the water temperature. This is because suspended and dissolved particles absorb more solar radiation resulting in an increase in temperature (Pluhowski, 1970).

Most aquatic organisms survive at specific optimum temperature range. If water temperature is outside this range for a long time, organisms can be stressed and die (Lake *et al.*, 2000; Lodge, 2001; Poff *et al.*, 2001). Aquatic organisms are sensitive environmental to variations especially sudden temperature changes. Furthermore, temperature also affect the rate of photosynthesis in aquatic plants and sensitivity of organisms to toxic wastes, parasites and diseases (Poff and Ward, 1989).

In Kenya and most countries in the tropics solar radiation is high throughout the year. (Lalah *et al.*, 2001) The warm water temperature is attributed to the ambient air temperature and the water heating at mid day when the solar radiation is at its maximum (Bootsma and Hecky, 1993).

However, the Lake sometimes experience poor mixing of surface and sub-surface waters (Waltson, 2010). The cold water temperature in the early hours of the morning is caused by heat loss by specific conduction to the air (Verschuren, 1999). This holds more oxygen than warm water (USEPA, 1999) thus capable of supporting a diversity of aquatic organisms.

**2.3.2 Conductivity**

Sediments and solids arising from anthropogenic activities influence water conductivity. The Lake's catchment area is characterised by intensified cultivation resulting into the clearance of natural vegetation (Gaudet and Muthuri, 1981). These vegetations which served as filter retaining sediment from upstream during period of rains had been cleared increasing the amount of sediments and chemical residue reaching the Lake. As such, the inflow at the northern end of the Lake may contain a large amount of sediment thus fluctuation in conductivity levels (Kitaka *et al.*, 2002). The Sediment and solid particles absorb chemicals resulting in the rising conductivity levels.

Conductivity of water is function of the concentration of dissolved ions (Tenagne, 2009). It indicates the presence of inorganic materials in the water (Tenagne, 2009). A suddenly increase in conductivity indicates source of dissolved ions in the vicinity. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems. The recommended surface water for drinking should have conductivity range of between 0-800 $\mu Scm^{-1}$ (Tenagne, 2009). Conductivity varies from about 1.0 $\mu Scm^{-1}$ for freshly distilled water to about 1000 $\mu Scm^{-1}$ for highly mineralised water which is an indicator of pollution (USEPA, 2001). Low conductivity is often characteristic of forested rivers (Chapman and Chapman, 2003).

It was imperative to note that other lakes in Rift valley namely Baringo, Nakuru and Bogoria's were analysed for conductivity. Lake Baringo's conductivity range was 221-2110 $\mu S\ cm^{-1}$; Lake Nakuru's conductivity range was 27185-48455 $\mu S\ cm^{-1}$ (Shivoga., 1999; 2001) and Lake Bogoria's conductivity range 72000 $\mu S\ cm^{-1}$ (Melack, 1981) while Lake Naivasha's range of 233-480 $\mu S\ cm^{-1}$ ( Harper *et al*., 1990). This explains why the Lake has fresh water unlike the other lakes in Rift valley supporting many forms of aquatic life and attracting large numbers of water bird.

**2.3.3 pH**

Water pH is a function of nature of discharges in waste water (USEPA, 2003). The safe aquatic habitat range is between 6.5 and 8.5 (Environment Canterbury; Resource care guide, 2005). Most aquatic organisms are adapted to a specific pH level and may die, stop reproducing or move away if the pH of the water varies beyond a certain range. pH is the main control of chemical and biological activities thus it affects the Lake's biodiversity. The solubility of many toxic chemicals is influenced by the pH. As acidity increases, chemical become more water soluble hence more toxic.

The invasion of the Lake especially, during wet season may contribute to decrease in visibility which affects photosynthesis. The resultant effect of this phenomenon is the decrease in oxygen and increase in carbon dioxide levels which has catastrophic effects on the aquatic fauna e.g. fish kills (Howard and Harley, 1998) due to low pH. Low oxygen levels coincide with low pH values, furthermore in oxygen deficient areas fish catch are low (Westernhagen and Dethlefsen,1983).

It was imperative to note that in comparison to other lakes in Rift Valley, Lake Baringo's pH range of 6.11-10.00, Lake Nakuru's pH range of 9.21-10.60 (Shivoga, 1999; 2001) while, Lake Naivasha's pH range of 7.7-8.5 (Harper *et al.*, 1990). This explains why the Lake is the only fresh water lake in Rift valley. The balanced pH makes this habitat to be conducive for many forms of aquatic life, attracting large numbers of water birds.

### 2.3.4 Turbidity and Total Suspended Solids (TSS)

Water turbidity is a function of concentration, fineness or dispersion of the suspended matter and the light absorption of the suspension while Total Suspended Solids is a function of level of suspended solids (organic and inorganic) present in water sample (APHA, 1998). These parameters may indicate the entrance of surface wash and thus potential contamination. Lind *et al.*, (1992) noted that the extent of re-suspension is a function of depth, fetch, wind velocity and nature of sediment, which include sizes and densities. The Lake experience wind perturbation during the wet season. The wet season is accompanied by strong water currents and increased air movement (Waltson, 2010).

Sediment and solid particles in water originate from surface runoff from agricultural fields (Sansalone *et al.*, 2008).The intensive land use and soil erosion in the catchment area which is enhanced during wet season due to high sediment load according to Kitaka *et al.*, (2002).

Suspended solids in water adsorb chemicals as they are carried on the surface of particles. The smaller the particle size, the greater the surface area per unit mass of particle, and so the greater the pollutant load that is likely to be carried. Higher levels of suspended solids, increases turbidity while it lower transparency (Sansalone *et al.*, 2008).

Turbidity is function of suspended and dissolved material and colloidal matter such as clay, silt, organic and inorganic matter, and microscopic organisms (APHA, 1985). Turbid water may be a result of soil erosion, urban runoff, algal blooms and bottom sediment (APHA, 1985).Turbidity influences other physicochemical parameters. For instance, high turbidity raises the temperature of water, thereby leading to low Dissolved Oxygen concentration which inhibits water from supporting a diversity of aquatic life.

Total Suspended Sediment (TSS) is a function of suspended solids in water, which may be mineral or organic material. High levels of TSS reduce light penetration in the water column, which may then reduce photosynthesis of submerged aquatic plants (APHA, 1985). Total Suspended Sediment (TSS) may also result in abrasive action, loss of visual efficiency in feeding and interfere with food gathering ability by filter feeder micro invertebrates (Wagener and LaPerriere, 1985). Furthermore, the suspended particles are carrier for pesticides components (Dwinker *et al.,* 1982).

### 2.3.5 Dissolved oxygen

Dissolved Oxygen is a function of pressure, altitude and dissolved organic matter, which may be derived from natural or anthropogenic sources (USEPA, 1990). Natural waters with consistently high Dissolved Oxygen levels are most likely to be healthy and stable environment, and are capable of supporting a diversity of aquatic organisms (USEPA, 1999). Low Dissolved Oxygen levels are known to be harmful to many aquatic organisms (Chapman, 1996).

The Lake's altitude (1884 m.a.s.l) (Harper, 1993; Becht *et al.*, 2005) contributed to its high Dissolved Oxygen level. Since, altitude promotes the dissolution of oxygen in water but, this is limited to11 $mgl^{-1}$ as this is a function of pressure (Bootsma and Hecky, 1993). Occasionally, the Lake's shores experience high level of invasion by macrophytes especially, during the wet season leading to high algae growth whose decomposition consumes by far a large volume of oxygen than consumed by both animals and plants (Wetzel, 1983) lowering Dissolved Oxygen levels.

**2.3.6 Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)**

Organic and inorganic materials arising from anthropogenic activities around the Lake influence levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). These parameters are used to evaluate organic matter content in water though Biochemical Oxygen Demand is more accurate and Chemical Oxygen Demand is only used as confirmatory purpose.

Both Biochemical Oxygen Demand and Chemical Oxygen Demand evaluates the level organic content thus, estimating the degree of water pollution (AOAC, 1990). Their high levels are attributed to surface run off which carries with it organic and inorganic material entering the Lake (Harper *et al.*, 1990). Fish exposed to lethal levels of Organochlorine (0.10 ppm) results in an increase of their oxygen demand and metabolic activities 2-3.5 times as those in normal conditions (Waiwood and Johasen, 1974). The increase in the in oxygen demand is associated to the increased in the uptake of pesticides thereby explain the irreversible nature in fish which includes loss of balance and coordination (Waiwood and Johasen, 1974).

**2.4 The pesticide residue level of organophosphate and organochlorine in Lake Naivasha**

The World Health Organisation maximum pesticide residue limits are based on toxicological data and they therefore consider pesticides individually as pesticides differ from one another on their toxicological properties (WHO, 2000). Moreover, even low concentration of some pesticide residues can have adverse biological or health effects (WHO, 1990; ATSDR, 1994; Connell, 1997; ATSDR, 1999).

There were a number of cases of pesticides contamination in the environment reported in the country (Getenga *et al*., 2004; Wandiga *et al*., 2002). Furthermore, improper storage and lack of sound disposal facilities have caused contamination of soil, water, air, plants and animals (FAO, 1998). Therefore, they should be handled, used and stored with great care and precaution (PCPB, 1998) for their differential effects are based on their concentration (IPCS, 2005).

Pesticides are cost and time effective measure for pest control compared to physical removal which are expensive and tedious (Kengara, 2003). An appropriate use of pesticides based on recommendation is generally expected to cause little adverse impact on the environment (Getenga *et al*, 2000). However, abuses of pesticides could cause great environmental and public health concerns (WHO, 1990). The Pest Products Acts, Cap 346, Pest Control Product Board has the mandate of regulating agrochemicals to ensures that only safe, efficacious and quality pesticides are used in the country. Furthermore, the body is mandated to give guidance and regulatory role through provision of adequate and correct information on safe handling, use and disposal of pesticides.

Pesticide residues analysis carried out in the early 2000 at Lake Naivasha by the International Institute of Aerospace Survey and Earth Sciences (IIASES) revealed detectable levels of Organochlorine pesticide residues in water samples (Jolicoeur, 2000; Janeth, 2001). Organochlorine and Organophosphate pesticide residues have significant threat to life. Their occurrence has toxicological effects on water and water birds. Organochlorine pesticide residues are persistent in the environment and have tendency to accumulate significantly through the food chains (UNEP, 2003). Furthermore, they are persistent (Betlem *et al.*, 1998; Buchel, 1983) namely: Dichlorodiphenyl-trichloroethene and Lindane takes 10 and 6.5 years respectively to dissociate (Edwards, 1973).

Globally, the use of Organochlorine and Organophosphate pesticide had drastically declined following the ban on their production (U.S. Geological Survey, 2005). Despite this, they are still present in the Kenyan market namely: Lindane restricted for seed dressing (Jeffrey *et al.*, 1981; Tanabe *et al.*, 1993) while Aldrin and Dieldrin restricted to termite control in the building industry (PCPB, 1998). In Kenya, Lindane was introduced in 1949, Dichlorodiphenyl-trichloroethene in 1956 and Dieldrin in 1961 (Lalah *et al.*, 2001; Lalah *et al.*, 2003). Since then, they have been widely used because they had proved to be effective in eradicating pest (Wandiga, 1995). Farmers will not fully comply to abandon them so long as they were still available in the market. Market research conducted in the vicinity of the Lake shown them being highly preferred by farmers (Jolicoeur, 2000; Janeth, 2001; Gitahi *et al.*, 2002).

Organophosphate which has been adopted as alternative to Organochlorine pesticides due to their rapid degradation (Lalah and Wandiga, 1996; Gitahi *et al.*, 2002) and low deposition rate due to their high solubility in water and potential hydrolysis degradation (Ji-Zhong *et al.*, 2012) although, they are highly toxic to vertebrates (Oscar, 2007; UNEP, 2003).

There are various conservation efforts in the Lake and its environs in an attempt to restore the Lake's ecosystem (David *et al.*, 2011). Furthermore, Environmental Management and Coordination Act established in 1999 requires Environmental Impact Assessment and Environmental Audit be carried out for large scale agricultural activities.

**2.5 The effect of water contamination on water bird numbers in Lake Naivasha**

The Lake and its environs supported diverse water bird community (Harper *et al.*, 1990). Survey based on regular counts generated reports which were compiled in August 1987, 1990 1991and 1992 (The Earth watch/Leicester final reports to Government of Kenya). These reports were showing abundance of waterfowl (around 35,000 individuals at least 350 bird species of which 90 are aquatic or semi aquatic (Bennun *et al.*, 2002; Clark *et al.*, 1989). Many birds' species had been recorded in the Lake and its environs over the years as it serves as an important stop over point for water birds. The water bird biodiversity and abundance appear strongly linked with the habitat diversity i.e. availability of a wide range of food items (Boar *et al.*, 2002).

The Lake and its environs and serves as an important area for conservation of migratory, vagrant and resident water birds. This wetland arrays had a well known and diverse avian fauna, Ramsar site and an important bird area (IBA)-code KEO48 (Otieno *et al*., 2004; Bennun and Njoroge, 1999). According to Furness and Greenwood (1993) the assessment of abundance and distribution of water birds was an independent ways of monitoring aspect of poor water quality. Changes in water bird numbers is a reflection of effects of changes taking place in Lake's ecosystem (Henderson and Harper, 1992). The Earth watch (Leicester) final reports conducted from 1991-2000 to Government of Kenya. The reports revealed a declining trend in the of water bird numbers. It was also noted that the mean values of all piscivorous birds in the Lake and its environs from 1991-1996 were on decline, especially *Fulica cristata* and *Haliaeetus vocifer*.

The Lake edge support dense vegetation which in turn supports the thriving bird population like Grey-capped Warbler, Spectacled weaver, Brimstone, Canary and Red-billed fire finch while the fish population attracts a variety of fish eaters like Long tail, Great cormorants, Fish eagle, Pied kingfishers, Watch back and Herm.

Harper *et al.,* (1990) shown that the Lake's native fish were facing extinction. This development caught the attention of scientists like Phil Hickley and David M. Harper to carry out further research in the Lake. According to their observation, the fish community at the time was under pressure from over-fishing, decreasing water levels and inadequate species diversity. This prompted the government of Kenya to impose a temporary periodic ban on fishing activities in Lake Naivasha since 2001 (Daily Nation Newspaper, 16th Dec, 2002). Furthermore, the introduction of exotic fish namely: crayfish in 1970 (Harper *et al.*, 2002) and common carp in 2001 (Brecht *et al.*, 2005) to enhance the Lake's biodiversity.

Water contaminated with Organochlorine and Organophosphate pesticides is dietary pathway through which these pesticides find their way into the tissues of water birds. The Organochlorine pesticide residues posed the greatest threat to water birds since their long-term use leads to their accumulation in the environment (IPCS, 2005). Moreover, they can reach high concentrations in the tissues of water birds which occupy advanced levels along the food chains through biomagnifications (Connell, 1997). Bioaccumulation rates depend on factors such as exposure concentrations as well as time (Nowak, 1995). The water birds accumulate high levels of toxic due to chronic exposure to sub lethal doses as they prey on other aquatic organisms for food. Once in the tissues of water birds they influence physiological and metabolic processes leading to reproductive failure, egg shell thinning and breeding failure, egg shell thinning and breeding failure, reduced egg hatchability and low survival rate of chicks (Spitzer *et al.*, 1978, Grier, 1982; Cade *et al.*, 1971; Nisbet, 1975). In addition, they affect fish causing egg-shell thinning and reduced egg hatchability (Mugacha *et al.*, 1992).The occurrence of Organochlorine and Organophosphate pesticide residues in the Lake's water influenced was reflected on the declining water bird numbers (Gitahi *et al.*, 2002; Furness and Greenwood, 1993).

**2.6 Conceptual framework**

The practice of over reliance on chemical pesticides to eliminate pest and diseases is common in modern agriculture (IAASTD, 2008) and the floricultural farms were no exception to pesticide use. The Organophophate (OP) and Organochlorine (OC) pesticide residues in water are carried by surface run off, rivers and streams eventually ending up into the Lake. Organophosphate pesticides are highly toxic to vertebrates (UNEP, 2003) while the Organochlorine pesticides are persistence and cumulative along the food chain of water birds as such, they have influence on water quality and water birds numbers. Water is a dietary pathway through which these pesticides get into body tissues of water birds. Once in the tissues they influence physiological and metabolic processes resulting to reproductive failure, egg shell thinning and breeding failure, egg hatchability failure and reduce in survival rates of chicks (Spitzer *et al.*, 1978, Grier, 1982; Cade *et al.*, 1971; Nisbet, 1975). The reduction in the birds' species richness in the Lake was an indication of underlying environmental problems (Bennun *et al.*, 2002). The Organophosphate pesticides are designed to harm the intended pest but they often kill other aquatic organisms present which water birds prey on (Standard Newspaper, 7th March, 2010) while Organochlorine pesticide residue have tendency to accumulate significantly through the food chain because they undergo limited decomposition. Their concentrations increase by order of magnitude through bioaccumulation and biomagnifications in water birds. Higher concentrations in the body tissues of water birds the leading to the declining water bird numbers as shown in figure 2.1.

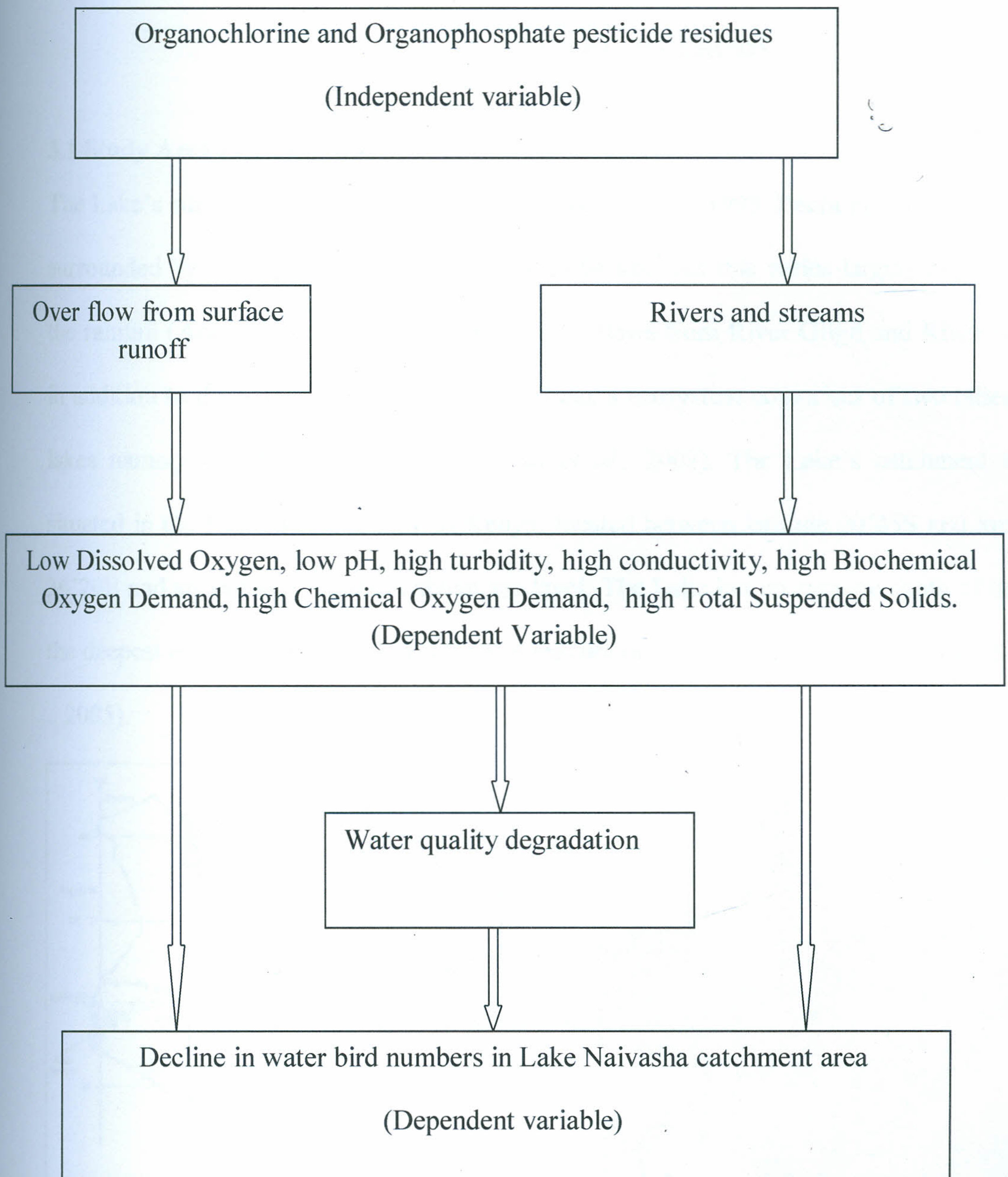


Figure 2.1 Conceptual framework

## CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Study Area and location

The Lake's surface area is approximately 140 km$^2$ (Harper, 1993; Becht *et al.*, 2005) and it is surrounded by swamps which cover an area of 64 km$^2$ but this varies largely depending on the rainfall (Arusei *et al.*, 2002). It receives its inflows from River Gilgil and River Malewa in addition to the underground seepage. The Lake's ecosystem comprises of two other small lakes namely Oloiden and Sonachi (Arusei *et al.*, 2002). The Lake's catchment area is situated in the Eastern Rift Valley of Kenya, located between latitude 00΄45S and longitude 36΄20E and an altitude of 1884m above sea level. The Lake has an average depth of 6m with the deepest area at Crescent Island Bay at a maximum depth of 30 m (Harper, 1993; Becht *et* ., 2005).

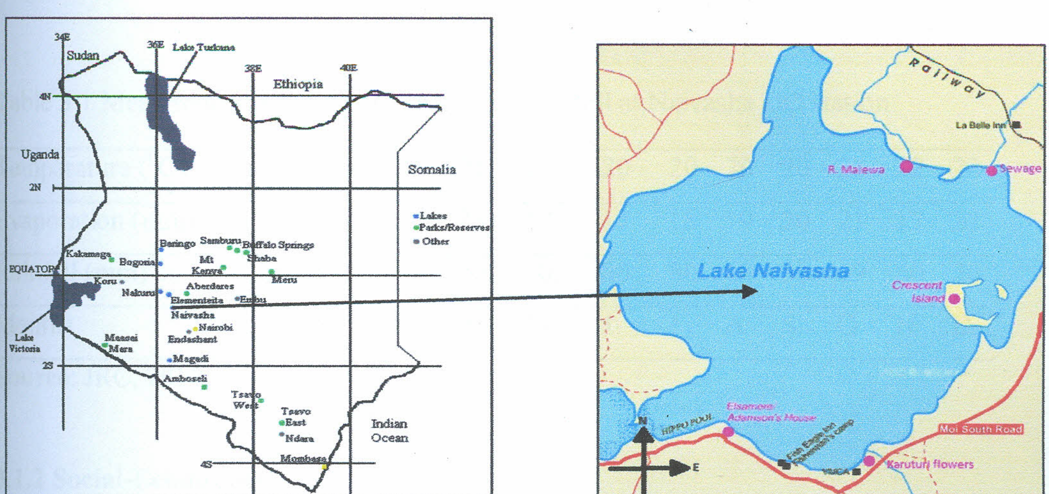


Figure 3.1 Map of Kenya and study location showing the sampling sites

**Source**: Lake Naivasha Riparian Association, 1999.

### 3.1.1 Soil Type

Alluvial and loamy soils are the most common soil types in Lake Naivasha catchment area (Arusei *et al*, 2002). The opening up of more land space for farming has lead to physical disturbance of vegetation making these soils particles to be carried by erosion to water bodies increasing turbidity and total suspended solids on the Lake's waters.

### 3.1.2 Climate

The climate of the region is warm and dry with maximum temperatures varying between 26°C and 30°C. The catchment receives rainfall between 500mm and 700mm per annum. Rainfall reliability is poor and unpredictable (Arusei *et al.*, 2002). The region rainfall is bimodal with the peaks in the months of April and October but shows inter annual irregularity and an annual evapo-transpiration that exceed total rainfall (Harper *et al.*, 1995). Furthermore, the region experience high solar radiation whose effects is felt throughout the year (Lalah *et al.*, 2001).Table 3.1 shows the mean temperature, evaporation and rainfall in Lake Naivasha.

Table 3 1 Mean temperature, evaporation and rainfall at Naivasha DO station

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature ($^0$C) | 21 | 22 | 22 | 21 | 20 | 20 | 20 | 20 | 20 | 21 | 22 | 22 |
| Evaporation (mm) | 27 | 28 | 27 | 23 | 17 | 17 | 18 | 19 | 20 | 21 | 17 | 22 |
| Rainfall (mm) | 21 | 30 | 30 | 80 | 100 | 80 | 80 | 60 | 30 | 69 | 60 | 30 |
| Months | J | F | M | A | M | J | J | A | S | O | N | D |

**Source**: JRC, 2010.

### 3.1.2 Social-Economics

The flourishing floriculture sector in Lake Naivasha catchment area has resulted in the influx of settlers most of whom practice farming. The Horticultural sector is the second foreign exchange earner after tourism (Harper and Mavuti, 2004). Tourism is also a major sector in the Lake and its catchment area. The wetland supports a growing human population as employment opportunities are created both in the farm and also on the resorts in the vicinity of the Lake.

### 3.1.3 Sample site description

The five sampling sites were highly differentiated namely: Karuturi Flower Farm Inflow, Sewage Inflow, River Malewa Inlet, Elsamere Conservation Centre and Crescent Island Lagoon as shown in figure 3.1. These sites were chosen based on the characteristics of their waste discharge while the two pristine sites served as control. The sites were fixed by detailed description and marked accordingly on the map of the Lake's catchment area using GPS system as follows: Elsamere (S 00′44 682 E 036′25 334), Crescent (S 00′ 46 041 E 036′ 25 044), Karuturi (S 00′ 49 258 E 036′ 21 825), Sewage (S 00′ 40 90 E 036′ 19 091 and Malewa (S 00′ 43 722 E 036′ 25 334).

**Site 1** Elsamere- the site is on the southern shore of Lake Naivasha and it is covered with natural vegetation and forests shown in plate 1, **Site 2** Crescent- the site is on the eastern shore of the Lake Naivasha and it is dominated with natural vegetations and forests (Arusei *et al.*, 2002) as shown on Plate 2, **Site 3** Karuturi- the site on the south east shores of Lake Naivasha and is dominated by flower farms as shown on plate 3,**Site 4** Sewage- the site is on the northern eastern shore of the Lake Naivasha and it serves Naivasha town as shown on Plate 4 and **Site 5** Malewa- the site on the northern shore of the Lake Naivasha and it is devoid of most natural vegetation as shown on Plate 5.

Plate 1. Elsamere Conservation Centre

Plate 2. Crescent Island Lagoon

Plate 3. Karuturi Flower Farm Inflow

Plate 4. Sewage Inflow

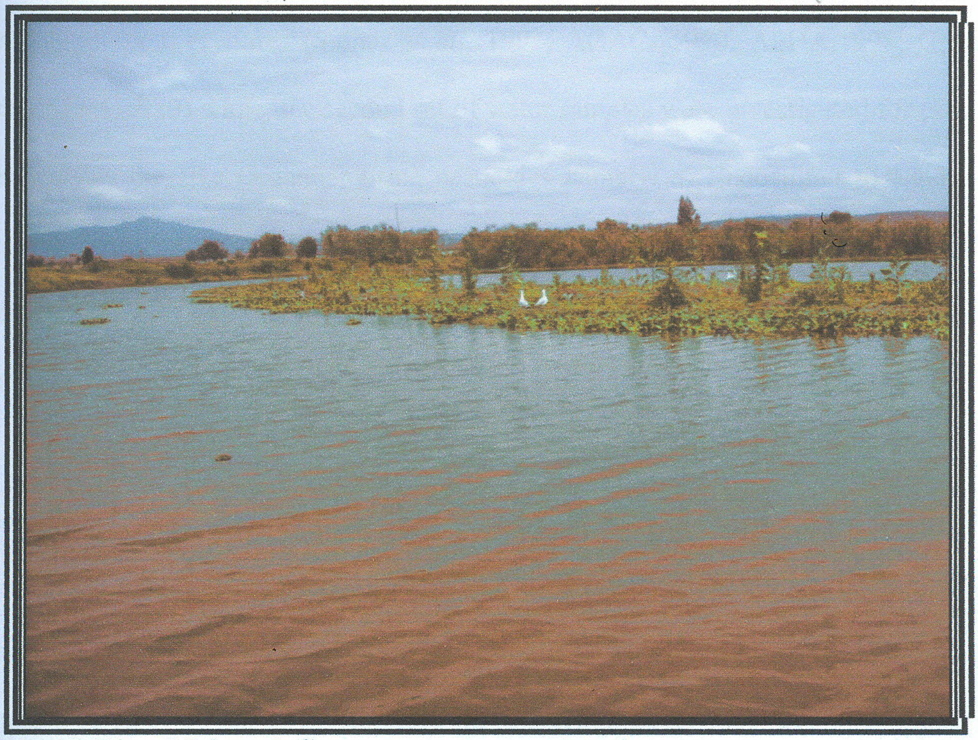

Plate 5. River Malewa Inflow

### 3.2 Research Design

This was longitudinal study involving ecological and laboratory investigations. The variables were namely: water physico-chemical parameters, pesticide residues analysis, and water birds numbers. The water samples were collected between February and July, 2011 at 10.00 a.m.-3.00 p.m. The duration of the study allowed for season variation to be investigated for it covered both dry and wet season. All the sampling sites were accessed using a motorboat between February and July 2011. The surveillance was carried out together with research assistants to aid in water sample collection and water bird counts along respective shoreline.

The first set of water samples were tested for physico-chemical parameters namely: i) Temperature ii) Conductivity iii) pH iv) Turbidity v) Dissolved Oxygen vii) Chemical Oxygen Demand viii) Biochemical Oxygen Demand ix) Total Suspended Solids using standard laboratory procedures (Sidnei *et al.*, 1992; AOAC, 1990; APHA,1998; Green *et al.*,1992, ESEPA,1979) while, the second set of water samples were investigated for pesticide residues analysis the five Organochlorine pesticides namely: a) Endosulfan b) Lindane c) Aldrin d) Dieldrin e) Dichlorodiphenyl-trichloroethene and the five Organophophate pesticides namely: a) Nemacur b) Orthene c) Durban d) Diazol e) Fenitrothion as described by Akerblom (1995) with few modifications.

Flexibility was paramount necessitating the use of three laboratories simultaneously considering that some variables were more likely to be affected by storage prior to analysis. For this reason determination of temperature was carried out in situ while water samples for Biochemical Oxygen Demand, Organochlorine and Organophophate were put under low temperature conditions until analysis to prevent deterioration and retard growth of micro-organisms.

### 3.2.1 Sample Size Determination

Three replicate of surface water samples were collected monthly, 18 water samples per site, totalling 90 while water birds counts were conducted at a fortnight interval. There was no mathematical formula applied to calculate sample size due to the discrete nature of variables. However, the sample size was sufficiently reasonable without compromising on the outcome yet making economic sense due to high cost involved in the chemicals analysis.

### 3.2.2 Water Sample Collection procedure

Sample bottles were rinsed out two or three times with the water to be sampled before collection. The three replicates of water samples with a capacity of 5 litres were collected at each site sum total of 75 litres of water per field visit. This volume was enough to take care of special determinations which required slightly larger quantities of water.

Water samples were collected from the side of the boat at each sampling sites from 2 metres from the edge of the floating plant mass to approximately 10 metre inside the Lake. All the water samples were attached with an appropriate inscribed label containing the: sample collector, the date, time, the source and exact location and the purpose to which the sample was taken to prevent contamination. The water specimens for Organophophate, Organochlorine and Biochemical Oxygen Demand analysis were chilled at $4^{0}$ C upon collection and stored at $6^{0}$ C until extraction to prevent deterioration.

### 3.2.3 Data Collection Instruments

The instruments used for this research were: i) Conductivity metre ii) Thermometer iii) Photoelectric turbidimeter iv) Glass cells with stopper v) pH meter vi) Vacuum flask and pump vii) Rubber adapter viii) Filter ix) Incubator x) Oxitop with magnetic stirrer xi) Digestion vessels xii) Pipette xiii) Burette. The choice of apparatus at any one moment depended on the variable to be analysed, choice of location, the frequency of sampling, weather conditions and the purpose of investigation. The data collection process was guided by the work plan while the laboratory investigations were guided by scientific procedures (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.2.4 Training of observers

The research assistants went through orientation programme at the initiation of the study. The collected water samples were registered in the laboratory with their details using a check lists. The ecological study of water birds was guided by a comprehensive chart containing sufficient details and descriptions of the birds to be observed, the date, hour and prevailing weather condition were used.

### 3.3 Measurement of water physico-chemical parameters

These included water Temperature, Conductivity, Turbidity, pH, Total Suspended Solids, Dissolved Oxygen, Chemical Oxygen Demand and Biochemical Oxygen Demand.

#### 3.3.1 Water temperature

The surface water temperatures measurements were carried out in situ at the time of sampling in the field using a thermometer.

#### 3.3.2 Conductivity

The analysis of water specimens were carried out at Kisumu Water and Sewage Company's and Lake Victoria Water Board's Laboratories. The collections were carried out within the five sampling sites for the test of water conductivity. At the time of testing the water temperature of the samples was recorded as $27.5^0$C hence the values obtained was not computed to be at $25^0$C as required. These values were measured using a probe (conductivity meter) standardized using standard solution of concentration 0.01M of potassium chloride. This was estimated by multiplying the conductivity value by empirical factor which varies from 0.5-0.9 depending on the soluble constituents and temperature of measurement (Chapman, 1996).

#### 3.3.3 pH

The analysis of water specimens for pH was carried out at the Central veterinary laboratory, Kabete. Water samples were collected across the five sampling sites and subjected to pH meter.

#### 3.3.4 Turbidity

The analysis of water specimens for turbidity was carried out at Kisumu Water and Sewage Company Laboratory. The samples were analyzed against the standards for drinking water KS 459 part 9 (Sidnei *et al.*, 1992; Chapman, 1996). Water samples were collected within the five sampling sites and subjected to photoelectric turbid-meter. It involves filtering a sample to collect suspended solids, then weighing the amount. The sample is filtered through a glass fibre filter 4.25cm diameter (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.3.5 Dissolved Oxygen

The analysis of water specimens for Dissolved Oxygen was carried out at Lake Victoria Water Board Laboratory. Water samples were collected within the five sampling sites and subjected to a standardized probe using standard iodine solution 0.025N (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.3.6 Chemical Oxygen Demand

The analysis of water specimens for Chemical Oxygen Demand was carried out at Lake Victoria Water Board Laboratory. Water samples were collected across the five sampling sites and subjected to a standardized probe using Standard Ferrous Ammonium sulphate (FAS) 0.1 M. (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.3.7 Biochemical Oxygen Demand

The analysis of water specimens for Biochemical Oxygen Demand was carried out at Lake Victoria Water Board Laboratory. The water samples within the five sampling sites were collected and kept at 4°C and analysed within 24 hours after sample collection while subjected to a standardized probe using KOH for 5 days (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.3.8 Total Suspended Solids

The analysis of water specimens for Total Suspended Solids was carried out at Lake Victoria Water Board Laboratory. Water samples were collected within the five sampling sites and subjected to a standardized filtration process (Sidnei *et al.*, 1992; Chapman, 1996).

### 3.4 Organochlorine (OC) and organophosphate (OP) analysis

The pesticide residue analysis focussed on Organochlorine and Organophophate pesticide while targeting five molecules from each of these two groups of pesticides. The water samples were subjected to Gas Liquid Chromatography due to its accuracy in detecting low quantities of these analytes. The sampling was done using standard methods as described by Akerblom (1995). The water samples were analysed without prior filtering so that the residues which had been adsorbed on the surface of suspended particles, especially the organic particles like humus (Ramulus, 1985) could be detected. Unfiltered water samples (100ml), previously preserved with 10% NaCl were extracted by Liquid-Liquid Extraction (LLE) method (Akerblom, 1995). The analytes were extracted using the mixed solvent (hexane/diethylether) in the ratio 85%: 15% as described in the reference (Green *et al.*, 1992) and shaken vigorously using a mechanised shaker for one hour and subsequently supernatant layers extracted. The extracted supernatants appeared clean and thus were not subjected to further clean up. The supernatants were concentrated to 2 ml by using rotary evaporator with water bath (Sieber and Notling, 1982). Further precautions were taken to ensure that there was no residual water left in the preparation. Once ready, 2 µl aliquots of both reference standards and the extracts were injected into the column, and the comparison was made between the standards and the samples based on the retention times, and the total area under the peak on the chromatograms. During the identification the peak was not considered relevant unless it had the same peak as the standard as presented on the chromatograms. Quantification of analytes was done by using the peak heights and the internal standards method (Martens *et al.*, 1999). The peak area of the compounds in the samples and those of the standard resulted into a ratio. The ratio was multiplied by the concentration of pesticides standard which was at 1µg /ml (ppb) (Green *et al.*, 1992).

GLC set up had the following accessories: syringe, analytical column, gases, suitable detector and a printer. Initially, before running any sample, it was confirmed that all parts of the equipment in contact with the samples and the reagents are interference free through analysis of method blank as a continuing check and safe guard against chronic laboratory contamination. The procedure was carried out at the Central Veterinary Laboratory, Kabete. A varian model equipped with ECD/NPD operating under the following conditions: Oven temperature $170^0$ C for 1.5 minutes, ramp rate $15^0$ per minute, oven no. II $170^0$ C for 0.5, ramp rate@ $25^0$ per minute to hold for 1 minute, column 3% OV 17, injector temperature $350^0$ C ECD/NPD detector type and detector saturation below 1 (specific 0.4) in water bath as shown on plate 6.

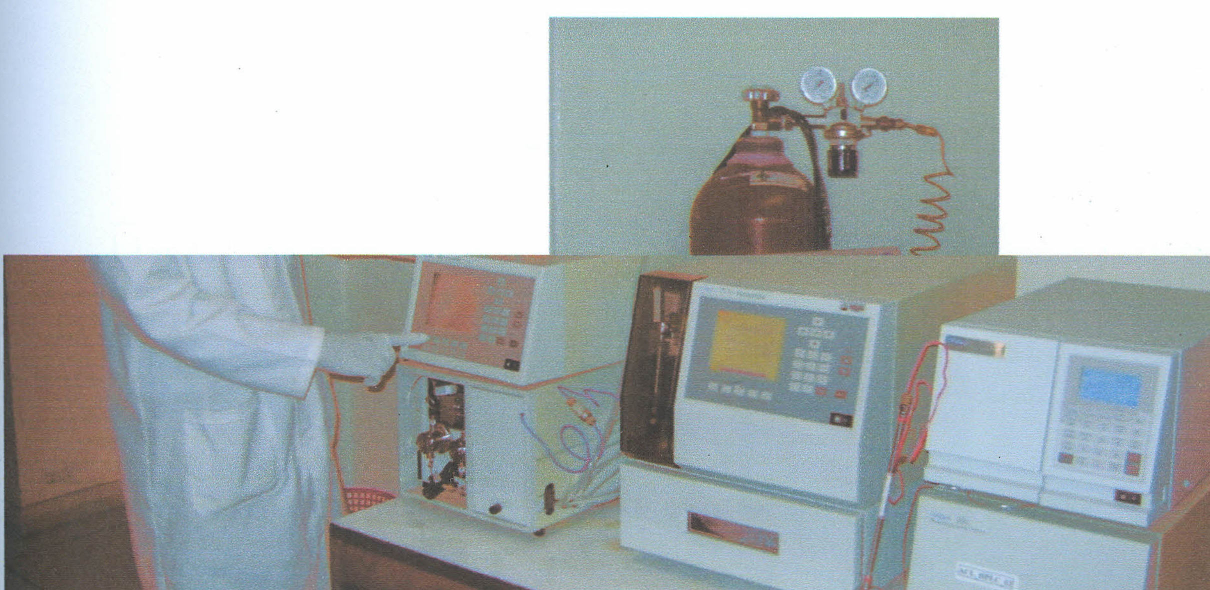

Plate 6. GLC set of apparatus

Gas Liquid Chromatograghy analysis procedure involved extraction, clean up and analysis of residual Organochlorine and Organophosphate pesticide residues. The Nitrogen-Phosphorus Detector (NPD) was used to analyse OP pesticide residues while Electron Capture Detector (ECD) was used to analyse OC pesticide residues as shown in figure 3.2.

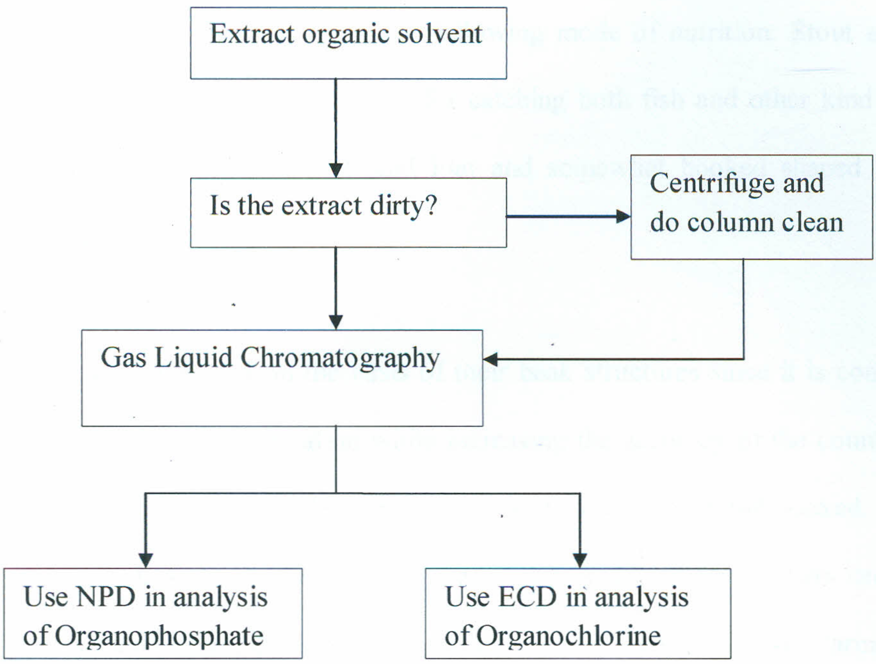


Figure 3.2 Summary of Gas Liquid Chromatography

### 3.5 The abundance and distribution of the water birds within the shores of Lake Naivasha

The water birds are tertiary consumers thus occupying the advanced level on the food chain of the Lake's ecosystem. Furthermore, they have a long life span which makes them an ideal bio-indicator of ecological changes of a habitat (Furness and Greenwood, 1993). This ecological study aimed at monitoring the distribution and abundance of the water birds across the five sampling sites. Boats were used to reach locations not accessible by land. The following apparatus were carried along: binoculars with a magnification six times to capture all the details clearly, bird identification guide, field note book with a pen, a map and a camera.

The study used water birds as indicator species to reflect on the ecological changes in the Lake's ecosystem since they are adapted to this habitat by possessing different types of beaks These beak structures enable them to fit the following mode of nutrition: Stout and spear shaped beak for spearing fish; Hooked beak for catching both fish and other kind of prey; Long and stout beak for scooping fish and Flat and somewhat hooked shaped beak for straining algae and small invertebrates.

The water birds were identified on the basis of their beak structures since it is conspicuous and reduces the risk of misinterpretation while increasing the accuracy of the counts. These were namely: i) Hooked ii) Stout and spear iii) Long and stout iv) Flat and hooked. The sites were numbered 1, 2, 3, 4 and 5 where by each site was represented by numbers namely : 1- Elsamere Conservation Centre; 2- Crescent Island Lagoon; 3- Karuturi Flower Farms Inflow: 4- Sewage Inflow and 5- River Malewa Inlet in that order.

The counts were carried out simultaneously at a fortnight interval using belts transect method while recording the birds' numbers on a prepared chart at each of the five sites. The procedure involved creating five imaginary lines parallel to each other at interval of 25m along the 100m shoreline i.e. at 1m, 25m, 50m, 75m and 100m mark respectively. Between each of the five parallel lines, four imaginary squares measuring approximately 10m were laid down. These were called transects A, B, C and D respectively each transect measuring $100m^2$. The counts were guided by a chart and the map of the catchment area (Dale *et al.*, 1999). Counting was aided by binocular to bring the far images of water birds closer thus reducing interference which could have arisen if they were to be approached at close range. All the water birds within transects A, B, C and D were counted simultaneously and recorded accordingly while using the chart to guide tallying process. An index of numbers were obtained as we moved a standard route at a steady standard rate and counted the water birds as they were observed and recorded on a prepared chart.

### 3.6 Data Analysis

The study generated data for evaluation of Lake Naivasha and its environs. These were recorded in a Microsoft Excel spread sheets and subjected to Statistical Package of Social Science (SPSS) using one way ANOVA at $p < 0.05$ level of significance for probability. The data were analysed and the results presented in tables and graphs. The descriptive statistics criterion applied summarized and evaluated significant findings. These were further compared to the World Health Organization and Kenya Bureau of Standards recommended compliance guidelines for surface water quality (Appendices I, II, III and IV).

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Introduction

The results of the study on water physico-chemical parameters were namely i) Temperature ii) Conductivity iii) pH iv) Turbidity v) Dissolved Oxygen vi) Chemical Oxygen Demand vii) Biochemical Oxygen Demand viii) Total Suspended Solids. The study on pesticide analysis focused on: i) Organochlorine pesticides namely: a) Endosulfan b) Lindane c) Aldrin d) Dieldrin e) Dichlorodiphenyl-trichloroethene ii) while on Organophosphate pesticides were namely: a) Nemacur b) Orthene c) Durban d) Diazol and e) Fenitrothion residues in water. The ecological study on water birds generated data as presented on the tables and graphs.

### 4.2 Water physico-chemical parameters

The results of the overall surface water physico-chemical parameters showing the mean and range values of variables measured in Lake Naivasha during a 6-month study (February to July, 2011) are shown in Table 4.1.

Table 4.1 Water physico-chemical parameters in Lake Naivasha from February to July, 2011

| Variable | Minimum | Mean ± SD | Maximum |
|---|---|---|---|
| Temperature (°C) | 12.0 | 20.5±3.40 | 27.5 |
| Conductivity($\mu Scm^{-1}$) | 447.0 | 594.1±81.3 | 738 |
| pH | 6.71 | 7.45±0.50 | 8.94 |
| Turbidity (NTU) | 2.13 | 15.15±9.93 | 39.43 |
| Dissolved Oxygen ($mgl^{-1}$) | 5.97 | 7.01±0.48 | 7.88 |
| Chemical Oxygen Demand ($mgl^{-1}$) | 27 | 66.5±67.30 | 300 |
| Biochemical Oxygen Demand ($mgl^{-1}$) | 11 | 31.1±32.30 | 184 |
| Total Suspended Solids ($mgl^{-1}$) | 2 | 22.4±14.90 | 59 |

The summarized surface water physico-chemical parameters quality standards (Appendices I, II, III and IV) according to World Health Organisation and Kenya Bureau of Standards as shown in table 4.2.

Table 4.2 World Health Organisation and Kenya Bureau of Standards quality Recommendations

| Variable | WHO/KEBS Guidelines |
|---|---|
| Temperature (°C) | <37 |
| Conductivity($\mu Scm^{-1}$) | < 1500 |
| pH | 6.0 -9.0 |
| Turbidity (NTU) | <5 |
| Dissolved Oxygen ($mgl^{-1}$) | > 4 |
| Chemical Oxygen Demand ($mgl^{-1}$) | 50 |
| Biochemical Oxygen Demand ($mgl^{-1}$) | 30 |
| Total Suspended Solids ($mgl^{-1}$) | 30 |

The World Health organisation and Kenya Bureau of Standards (Appendices I, II, III and IV) were summarized (Table 4.2). These water quality standards were used to evaluate the Lake's water quality on regards to its compliance to surface water suitability. The results (Table 4.1) indicated that water physico-chemical parameters were within the limits in compliance with World Health Organisation and Kenya Bureau of Standards (Table 4.2) namely:. Temperature 20.5°C (Table 4.1) compared to <37 °C (Table 4.2), Conductivity 594.1 $\mu Scm^{-1}$ (Table 4.1) compared to< 1500 $\mu Scm^{-1}$(Table 4.2), pH 7.45(Table 4.1) compared to 6.0 -9.0 (Table 4.2), Turbidity 15.15 NTU (Table 4.1) compared to <5 NTU (Table 4.2), Dissolved Oxygen 7.01 $mgl^{-1}$(Table 4.1) compared to> 4 $mgl^{-1}$ (Table 4.2), Chemical Oxygen Demand 66.5 $mgl^{-1}$(Table 4.1) compared to 50 $mgl^{-1}$ (Table 4.2), Biochemical Oxygen Demand 31.1 $mgl^{-1}$(Table 4.1) compared to 30 $mgl^{-1}$ (Table 4.2) and Total Suspended Solids 22.4 $mgl^{-1}$(Table 4.1) compared to 30 $mgl^{-1}$ (Table 4.2).

### 4.2.1 Seasonal effect on physico-chemical parameters

The results of the surface water physico-chemical parameters showing the mean and SD values of variables measured in Lake Naivasha during the dry season (February to April, 2011) are shown in table 4.3.

Table 4 3 Water physico-chemical parameters (Mean±SD) during dry season (n=45)

| Sample sites | Temp. (°C) | Conduct. (μScm$^{-1}$) | pH | Turbid. (NTU) | DO (mgl$^{-1}$) | COD (mgl$^{-1}$) | BOD (mgl$^{-1}$) | TSS (mgl$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Elsamere | 22±1.85 | 612±12.60 | 7.19±0.09 | 8.21±0.28 | 7.4±0.25 | 32±2.54 | 15±2.65 | 7±3.87 |
| Crescent | 24±2.05 | 490±11.80 | 7.16±0.05 | 2.67±0.52 | 7.3±0.30 | 32±3.32 | 14±1.36 | 9±3.74 |
| Karuturi | 22±2.11 | 590±29.04 | 7.15±0.15 | 24.30±2.23 | 7.0±0.42 | 64±25.01 | 30±8.44 | 36±16.18 |
| Sewage | 21±1.68 | 662±10 | 7.28±0.32 | 14.60±2.86 | 7.1±0.48 | 128±53.07 | 60±11.41 | 32±4.97 |
| Malewa | 16±2.70 | 468±26.28 | 7.43±0.59 | 23.27±3.19 | 7.0±0.54 | 32±2.65 | 16±5.54 | 34±6.24 |
| **Over mean** | **21.00** | **564.40** | **7.24** | **14.61** | **7.16** | **57.60** | **27.00** | **23.60** |

The results of the surface water physico-chemical parameters showing the mean and SD values of variables measured in Lake Naivasha during the wet season (May to July, 2011) are shown in table 4.4.

Table 4.4 Water physico-chemical parameters (Mean±SD) during wet season (n=45)

| Sample sites | Temp. (°C) | Conduc. (μScm$^{-1}$) | pH | Turbid. (NTU) | DO (mgl$^{-1}$) | COD (mgl$^{-1}$) | BOD (mgl$^{-1}$) | TSS (ml$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Elsamere** | 21±1.80 | 607±8.86 | 7.20±0.05 | 7.12±0.07 | 7.21±0.12 | 32±2.82 | 16±3.50 | 4±2.06 |
| **Crescent** | 23±1.68 | 490±12.63 | 7.16±0.07 | 3.68±0.28 | 7.1±0.38 | 32±3.00 | 14±2.06 | 6±3.43 |
| **Karuturi** | 21±2.15 | 680±15.64 | 8.1±0.38 | 25.1±1.40 | 6.4±0.54 | 64±21.49 | 32±7.45 | 32±10.31 |
| **Sewage** | 20±2.03 | 651±10.26 | 7.88±0.18 | 11.25±1.53 | 6.7±0.48 | 192±95.08 | 98±59.86 | 31±3.12 |
| **Malewa** | 15±1.96 | 691±22.32 | 7.95±0.84 | 31.25±5.57 | 6.9±0.36 | 32±2.00 | 16±5.17 | 33±6.78 |
| **Overall mean** | **20.00** | **623.80** | **7.66** | **15.68** | **6.86** | **70.40** | **35.20** | **21.2** |

Comparisons were made between values of physico-chemical parameters measured in the Lake during dry season (Table 4.3) and wet season (Table 4.4). These were aimed at finding out whether there were significant differences among the water physico-chemical parameters between the two seasons across the sampling site. The results (Tables 4.3 and 4.4) showed that there were no significant variations between sampling sites during both the wet and dry season. It was imperative to conclude that the Lake's overall water quality was not affected by seasonal variations.

### 4.2.2 Spatial dynamics of water physico-chemical parameters

The results of the surface water physico-chemical parameters showing the mean and SD of variables measured in Lake Naivasha during a 6-month study (February to July, 2011) at different sites has shown in table 4.5.

Table 4.5 Water physico-chemical parameters (Mean±SD) within different sampling sites

| | Sampling sites | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Elsamere** | **Crescent** | **Karuturi** | **Sewage** | **Malewa** | **Overall mean** |
| Temp. (°C) | $21.50\pm1.85^{B}$ | $23.61\pm1.95^{A}$ | $21.50\pm2.13^{B}$ | $20.50\pm1.88^{B}$ | $15.53\pm2.45^{C}$ | **20.5** |
| Conduct. ($\mu Scm^{-1}$) | $609.50\pm10.88^{BC}$ | $480.00\pm11.88^{D}$ | $635.00\pm51.54^{AB}$ | $656.50\pm11.28^{A}$ | $579.50\pm117.15^{C}$ | **594.1** |
| pH | $7.20\pm0.08^{B}$ | $7.16\pm0.06^{B}$ | $7.63\pm0.56^{A}$ | $7.58\pm0.40^{A}$ | $7.69\pm0.75^{A}$ | **7.54** |
| Turbidity (NTU) | $7.68\pm0.61^{D}$ | $3.16\pm0.66^{E}$ | $24.70\pm1.85^{B}$ | $12.93\pm2.81^{C}$ | $27.26\pm6.03^{A}$ | **15.15** |
| DO ($mgl^{-1}$) | $7.31\pm0.21^{A}$ | $7.20\pm0.37^{AB}$ | $6.70\pm0.56^{C}$ | $6.91\pm0.51^{BC}$ | $6.95\pm0.45^{BC}$ | **7.01** |
| COD ($mgl^{-1}$) | $32\pm2.61^{C}$ | $32\pm3.07^{C}$ | $64\pm22.62^{B}$ | $172.67\pm87.71^{A}$ | $32\pm2.28^{C}$ | **66.5** |
| BOD ($mgl^{-1}$) | $15.50\pm3.05^{C}$ | $13.94\pm1.07^{C}$ | $31.00\pm7.80^{B}$ | $79.00\pm46.15^{A}$ | $16.11\pm5.20^{C}$ | **31.1** |
| TSS ($mgl^{-1}$) | $5.50\pm3.38^{B}$ | $7.28\pm3.91^{B}$ | $34.00\pm13.32^{A}$ | $31.50\pm4.06^{A}$ | $33.50\pm6.35^{A}$ | **22.4** |

*Means with different superscripts in the same row are significantly different at $P<0.05$. (Data analyzed by Duncan's Multiple Range Test)

Water temperature levels within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)}$ =39.66, P<0.0001). Duncan Multiple Range Test (DMTR) established that the shore across Crescent Island Lagoon had the highest mean temperature (23.61°C) while River Malewa had the lowest mean temperature (15.53°C). It further established that the mean temperature within the shores where Elsamere Conservation Centre, Karuturi Flower Farms and Sewage Inflow had no significant difference.

The mean temperature recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet.seasons as shown in figure 4.1.

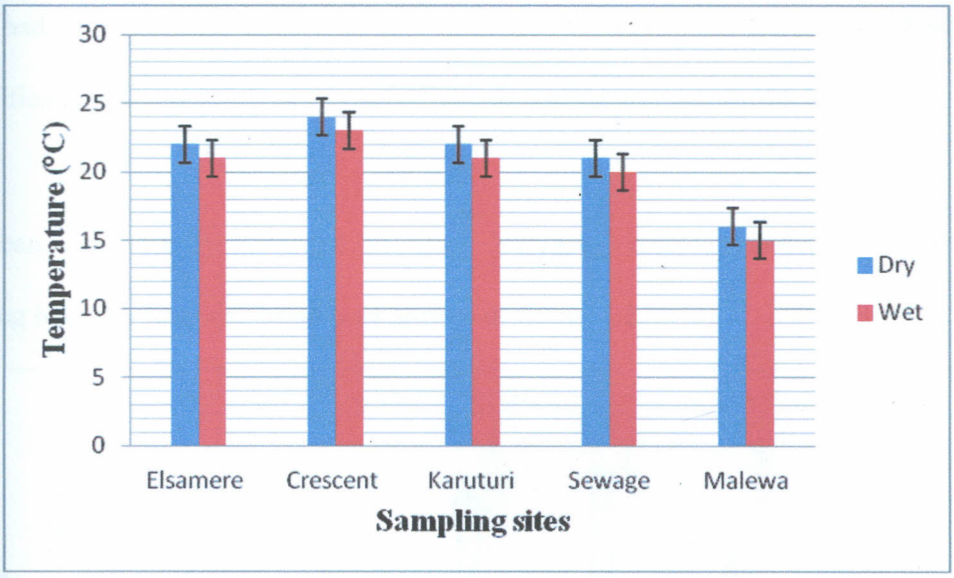


Figure 4.1 Mean temperature for two sampling seasons

The results showed that the highest mean temperature 24 °C (Figure 4.1) during dry season at Crescent Island Lagoon while the lowest mean temperaturewas 15°C (Figure 4.1) during wet season at River Malewa Inlet. The results showed that the mean water temperature range between wet and dry season was minimal with a difference of 1 °C (Figure 4.1) recorded across the sampling sites.

.Water conductivity levels within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)}$ =22.62, P<0.0001). Duncan Multiple Range Test (DMTR) established that the shore within Sewage Inflow had the highest mean conductivity (656.5$\mu Scm^{-1}$) while Crescent Island Lagoon had the lowest mean conductivity (490.00$\mu Scm^{-1}$). It further established that the mean conductivity within the shore of Sewage Inflow and Karuturi Flower Farms had no significant difference; Karuturi Flower Farms and Elsamere Conservation Centre had no significant difference and Elsamere Conservation Centre and River Malewa had no significant difference.

The mean conductivity recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.2.

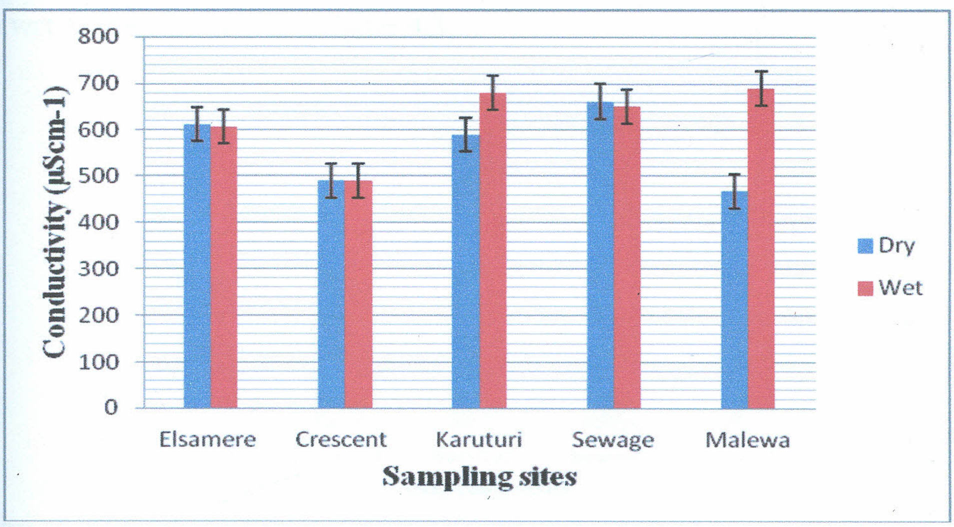


Figure 4.2 Mean conductivity for two sampling seasons

The results revealed that highest conductivity 691 $\mu Scm^{-1}$ (Figure 4.2) at River Malewa during the wet season while the lowest conductivity 468 $\mu Scm^{-1}$ (Figure 4.2) at Crescent Island Lagoon during both dry and wet season. The study noted that there were spatial variations in water conductivity among the sampling sites (Figure 4.2).

Water pH levels within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)}$ =5.42, P=0.0006). Duncan Multiple Range Test (DMTR) established that the shore within River Malewa had the highest mean pH (7.69) while Crescent Island Lagoon had the lowest mean pH (7.16). It further established that the mean pH of the shores within River Malewa, Sewage Inflow and Karuturi Flower Farms had no significant difference and Elsamere Conservation Centre and Crescent Island Lagoon had no significant difference.

The mean pH recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.3.

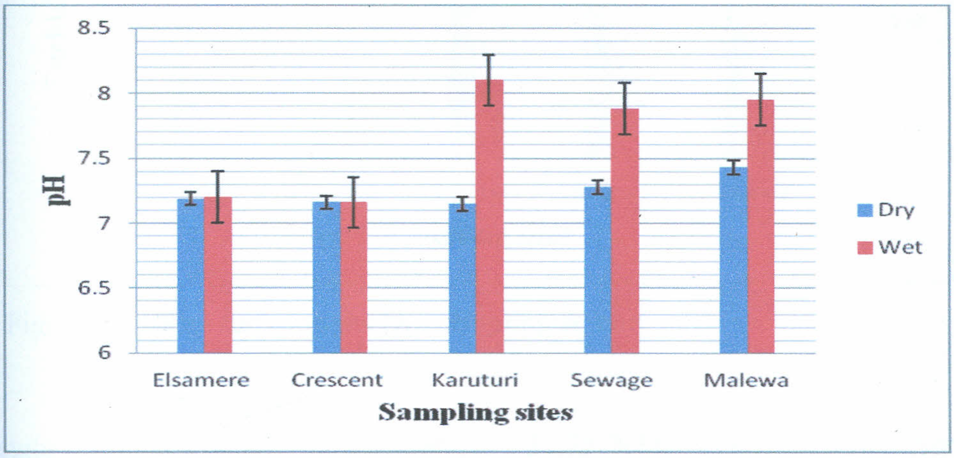


Figure 4.3 Mean pH for two sampling seasons

The results revealed that the highest pH 8.1 and lowest pH 7.15 (Figure 4.3) both at Katuturi Flower during wet and dry seasons respectively. However, the study noted an overall slight variation in pH as seasons changed from dry to wet across the five sampling sites (Figure 4.3).

Water turbidity levels within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)}$ =205.52, P<0.0001). Duncan Multiple Range Test (DMTR) established that the shore within River Malewa had the highest mean turbidity (27.26 NTU) while Crescent Island Lagoon had the lowest mean turbidity (3.18 NTU).

The mean turbidity recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.4.

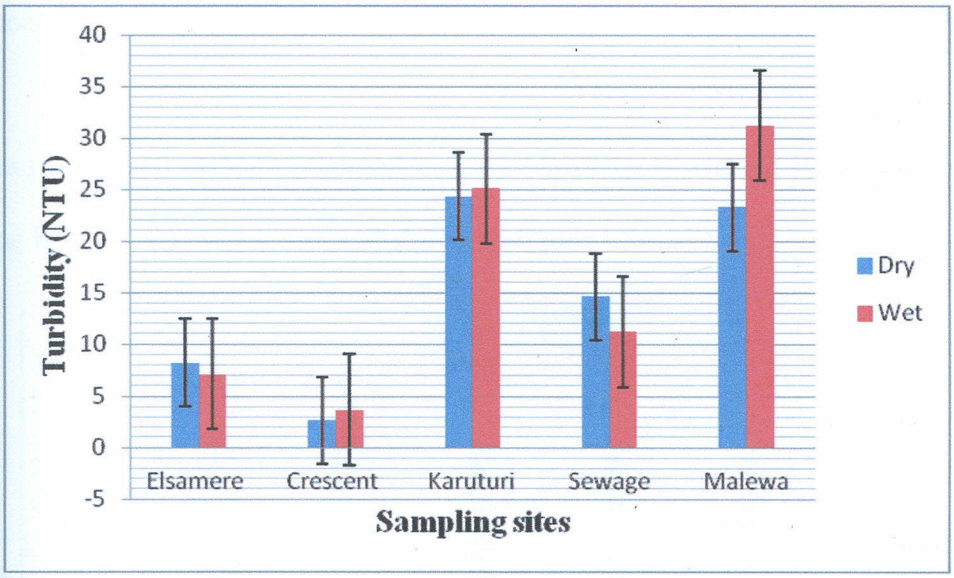


Figure 4.4 Mean turbidity for two sampling season

The results revealed that the highest Turbidity 31.25 NTU (Figure 4.4) at River Malewa Inlet during wet season while the lowest Turbidity 2.67 NTU (Figure 4.4) at Crescent Island during the dry season. The study noted that there was high variations among the sampling sites with the high values at activities sites compared to the prestine sites on regards to water turbidity

Dissolved Oxygen levels in water within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)} = 5.52$, P=0.0005). Duncan Multiple Range Test (DMTR) established that the shore across Elsamere Conservation Centre had the highest mean Dissolved Oxygen (7.31 $mgl^{-1}$) while Karuturi Flower Farms had the lowest mean Dissolved Oxygen (6.70 $mgl^{-1}$). It further established that the mean Dissolved Oxygen within the shores of Elsamere Conservation Centre and Crescent Island Lagoon had no significant difference; Crescent Island Lagoon, River Malewa and Sewage Inflow had no significant difference and River Malewa, Sewage Inflow and Karuturi Flower Farms had no significant difference.

The mean Dissolved Oxygen recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.5.

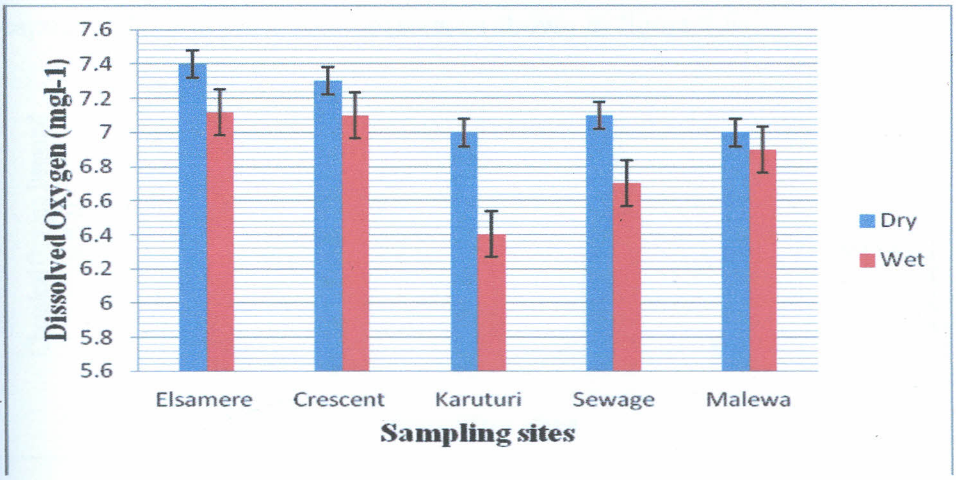


Figure 4.5 Mean Dissolved Oxygen for two sampling seasons

The results revealed that the highest Dissolve Oxygen 7.4 $mgl^{-1}$ (Figure 4.5) at Elsamere Conservation Centre during dry season while the lowest Dissolved Oxygen 6.4 $mgl^{-1}$ (Figure 4.5) at Karuturi Flower Inflow during the wet season.The study noted slight increase in Dissolved Oxygen across the sampling sites as seasons changed from dry to wet and spatial variation in Dissolved Oxygen levels among the sampling sites (Figure 4.5).

Chemical Oxygen Demand levels in water within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)} = 40.61$, $P<0.0001$). Duncan Multiple Range Test (DMTR) established that the shore within Sewage Inflow had the highest mean Chemical Oxygen Demand (172.67 $mgl^{-1}$) while Elsamere Conservation Centre, River Malewa and Crescent Island Lagoon had the lowest mean (32.00 $mgl^{-1}$). It further established that the mean Chemical Oxygen Demand across the shores of Elsamere Conservation Centre, River Malewa and Crescent Island Lagoon had no significant difference.

The mean Chemical Oxygen Demand recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.6.

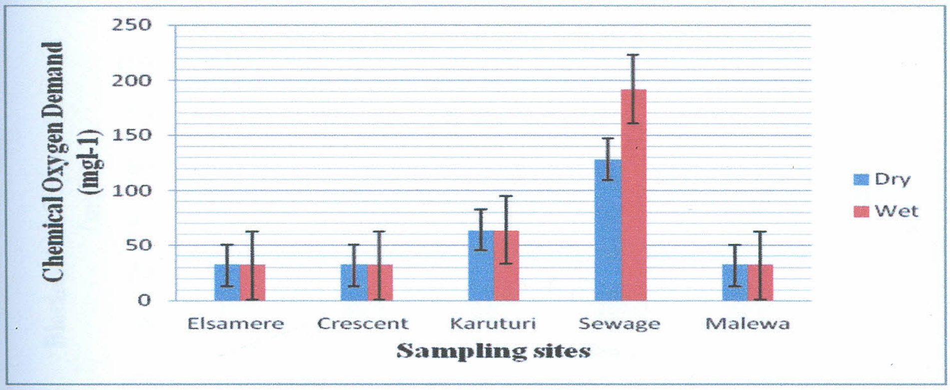


Figure 4.6 Mean Chemical Oxygen Demand for two sampling seasons

The results revealed that the highest mean Chemical Oxygen Demand 192 $mgl^{-1}$ (Figure 4.6) at Sewage Inflow during the wet season while the lowest Chemical Oxygen Demand 32 $mgl^{-1}$ (Figure 4.6) at both Elsamere Conservation Centre and Crescent Island Lagoon during both dry and wet seasons.The study noted that Sewage Inflow was outstanding among the sampling sites by having high levels of Chemical Oxygen Demand (Figure 4.6).

Biochemical Oxygen Demand levels in water within the shores of Lake Naivasha varied significantly between the sampling sites ($F_{(4, 89)}$ =30.85, P<0.0001). Duncan Multiple Range Test (DMTR) established that the shore within Sewage Inflow had the highest mean Biochemical Oxygen Demand (79.00 $mgl^{-1}$) while Crescent Island Lagoon had the lowest mean (13.94 $mgl^{-1}$). It further established that the mean Biochemical Oxygen Demand within the shores of River Malewa, Elsamere Conservation Centre and Crescent Island Lagoon had no significant difference.

The mean Biochemical Oxygen Demand recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet as shown in figure 4.7.

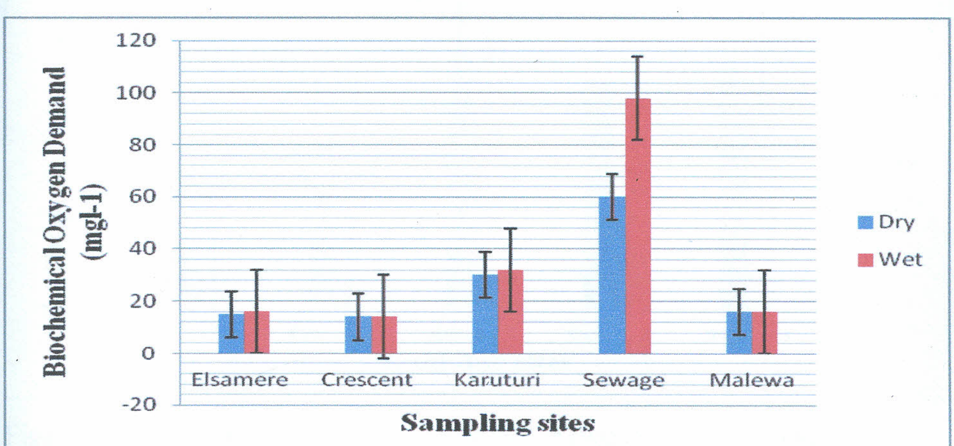


Figure 4.7 Mean Biochemical Oxygen Demand for two sampling seasons

The results revealed the the highest Biochemical Oxygen Demand 98 $mgl^{-1}$ (Figure 4.7) at Sewage Inflow during the wet season while the lowest 15 $mgl^{-1}$ (Figure 4.7) at both Crescent Island Lagoon and Elsamere Conservation Centre. The study noted that Sewage Inflow had an outstanding Biochemical Oxygen Demand.levels among the sampling sites.

Total Suspended Solids levels in water within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4, 89)} = 73.73$, $P<0.0001$). Duncan Multiple Range Test (DMTR) established that the shore within Karuturi Flower Farms had the highest mean Total Suspended Solids (34.00 $mgl^{-1}$) while Elsamere Conservation Centre had the lowest mean (5.50 $mgl^{-1}$). It further established that the mean Total Suspended Solids across the shores of Karuturi Flower Farms, River Malewa and Sewage Inflow had no significant difference and Crescent Island Lagoon and Elsamere Conservation Centre had no significant difference.

The mean Total Suspended Solids recorded in Lake Naivasha between February to July (6-months) capturing both dry and wet seasons as shown in figure 4.8.

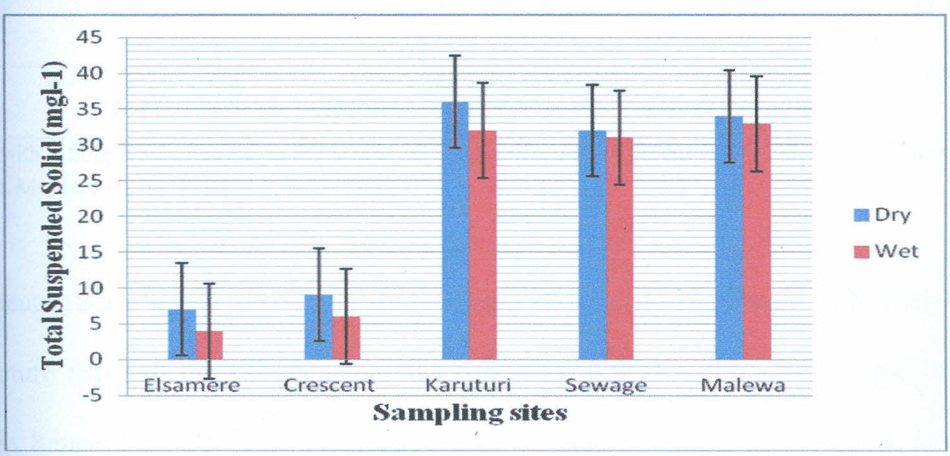


Figure 4.8 Mean Total Suspended Solids for two sampling seasons

The results revealed that the highest Total Suspended Solids 37 $mgl^{-1}$ (Figure 4.8) at the Karuturi Flower Inflow during the wet season while the lowest Total Suspended Solids 2.67 $mgl^{-1}$ (Figure 4.8) at Crescent Island Lagoon during the dry season.

### 4.2.3 Temporal dynamics of water physico-chemical variables

The results of the surface water physico-chemical parameters showing the mean and SD of variables measured in Lake Naivasha at different months during a 6-month study (February to July, 2011) has shown in table 4.6.

Table 4.6 Water physico-chemical parameters during the 6-months study of Lake Naivasha

| | Sampling months | | | | | | overall |
|---|---|---|---|---|---|---|---|
| **Parameters** | **February** | **March** | **April** | **May** | **June** | **July** | **mean** |
| **Temp. (°C)** | $21 \pm 3.32^{A}$ | $21.23 \pm 3.06^{A}$ | $20.9 \pm 4.03^{A}$ | $20.23 \pm 3.46^{A}$ | $20.37 \pm 3.25^{A}$ | $19.43 \pm 3.22^{A}$ | **20.53** |
| **Conduct. ($\mu Scm^{-1}$)** | $560.8 \pm 78.31^{B}$ | $562.6 \pm 83.07^{B}$ | $569.8 \pm 75.38^{AB}$ | $619.33 \pm 76.18^{AB}$ | $626.6 \pm 78.33^{A}$ | $625.47 \pm 75.65^{A}$ | **594.10** |
| **pH** | $7.2 \pm 0.29^{C}$ | $7.23 \pm 0.33^{A}$ | $7.29 \pm 0.33^{BC}$ | $7.59 \pm 0.57^{AB}$ | $7.69 \pm 0.58^{A}$ | $7.69 \pm 0.58^{A}$ | **7.45** |
| **Turbidity (NTU)** | $14.59 \pm 8.95^{A}$ | $14.57 \pm 9.01^{A}$ | $14.69 \pm 9.17^{A}$ | $15.6 \pm 11.23^{A}$ | $15.62 \pm 11.24^{A}$ | $15.82 \pm 11.53^{A}$ | **15.15** |
| **DO ($mgl^{-1}$)** | $7.26 \pm 0.42^{A}$ | $7.15 \pm 0.52^{AB}$ | $7.09 \pm 0.35^{AB}$ | $6.9 \pm 0.47^{B}$ | $6.84 \pm 0.52^{BC}$ | $6.82 \pm 0.48^{B}$ | **7.01** |
| **COD ($mgl^{-1}$)** | $57.13 \pm 45.55^{A}$ | $58 \pm 44.97^{A}$ | $57.67 \pm 48.57^{A}$ | $70.8 \pm 79.20^{A}$ | $64.6 \pm 60.48^{A}$ | $91.00 \pm 108.49^{A}$ | **66.53** |
| **BOD ($mgl^{-1}$)** | $26.4 \pm 18.29^{A}$ | $28.8 \pm 19.38^{A}$ | $27.87 \pm 20.35^{A}$ | $34.27 \pm 41.14^{A}$ | $35.47 \pm 41.82^{A}$ | $35.87 \pm 44.34^{A}$ | **31.11** |
| **TSS ($mgl^{-1}$)** | $23.67 \pm 15.70^{A}$ | $23.47 \pm 16.16^{A}$ | $23.67 \pm 14.93^{A}$ | $21.2 \pm 15.00^{A}$ | $21.07 \pm 15.07^{A}$ | $21.07 \pm 14.94^{A}$ | **22.36** |

*Means with different superscripts in the same row are significantly different at $P<0.05$. (Data analyzed by Duncan's Multiple Range Test).

Water temperature levels during the study period showed no significant difference in the mean temperature between the sampling months (one-way ANOVA, $F_{(5,89)}=0.56$, $p=0.729$). Duncan Multiple Range Test (DMTR) established that the water samples collected in March had the highest mean temperature (21.23°C) while July had the lowest mean (19.43°C) as shown in figure 4.9.

Water conductivity levels during the study period showed significant difference in the mean conductivity between the sampling months (one-way ANOVA, $F_{(5,89)}$=2.66, p=0.028). Duncan Multiple Range Test (DMTR) established that June had the highest mean conductivity (626.60 $\mu Scm^{-1}$) while February had the lowest mean (560.80 $\mu Scm^{-1}$). It further established that the mean conductivity in months of June, July and May had no significant difference and were significantly different from April, March and February which had no significant difference as shown in figure 4.10.

Water pH levels during the study period showed significant difference in the mean pH between the sampling months (one-way ANOVA, $F_{(5,89)}$=3.72,p=0.004). Duncan Multiple Range Test (DMTR) established that June had the highest mean pH (7.69) while February had the lowest mean (7.20). It further established that the mean pH in months of June, July and May had no significant difference; however, they were significantly different from April, March and February that had no significant difference as shown in figure 4.11.

Turbidity levels in water during the study period showed no significant difference in the mean turbidity between the sampling months (one-way ANOVA, $F_{(5,89)}$=0.05, p=0.9984). Duncan Multiple Range Test (DMTR) established that July had the highest mean turbidity (15.82 NTU) while March had the lowest mean (19.43 NTU) as shown in figure 4.12.

Dissolved Oxygen levels in water during the study period showed significant difference in the mean Dissolved Oxygen between the sampling months (one-way ANOVA, $F_{(5,89)}=2.38, p=0.045$). Duncan Multiple Range Test (DMTR) established that February had the highest mean Dissolved Oxygen (7.26 $mgl^{-1}$) while July had the lowest mean (6.82 $mgl^{-1}$). It further established that the mean Dissolved Oxygen in the months of February, March and April had no significant difference among themselves, however they were significantly different from June and July which had no significant difference between them while month of May had no different from both sets as shown in figure 4.13.

Chemical Oxygen Demand levels in water during the study period showed no significant difference in the mean Chemical Oxygen Demand between the sampling months (one-way ANOVA, $F_{(5,89)}=0.55$, $p=0.738$). Duncan Multiple Range Test (DMTR) established that July had the highest mean Chemical Oxygen Demand (91.00 $mgl^{-1}$) while February had the lowest mean (57.13 $mgl^{-1}$) as shown in figure 4.14.

Biochemical Oxygen Demand levels in water during the study period showed no significant difference in the mean Biochemical Oxygen Demand between the sampling months (one-way ANOVA, $F_{(5,89)}=0.28$, $p=0.921$). Duncan Multiple Range Test (DMTR) established that July had the highest mean Biochemical Oxygen Demand (35.87 $mgl^{-1}$) while February had the lowest mean (26.40 $mgl^{-1}$) as shown in figure 4.15.

Total Suspended Solids levels in water during the study period showed no significant in the mean Total Suspended Solids between the sampling months (one-way ANOVA, $F_{(5,89)}=0.12$, p=0.988). Duncan Multiple Range Test (DMTR) established that February had the highest mean Total Suspended Solids (23.67 $mgl^{-1}$) while July had the lowest mean (21.07 $mgl^{-1}$) as shown in figure 4.16.

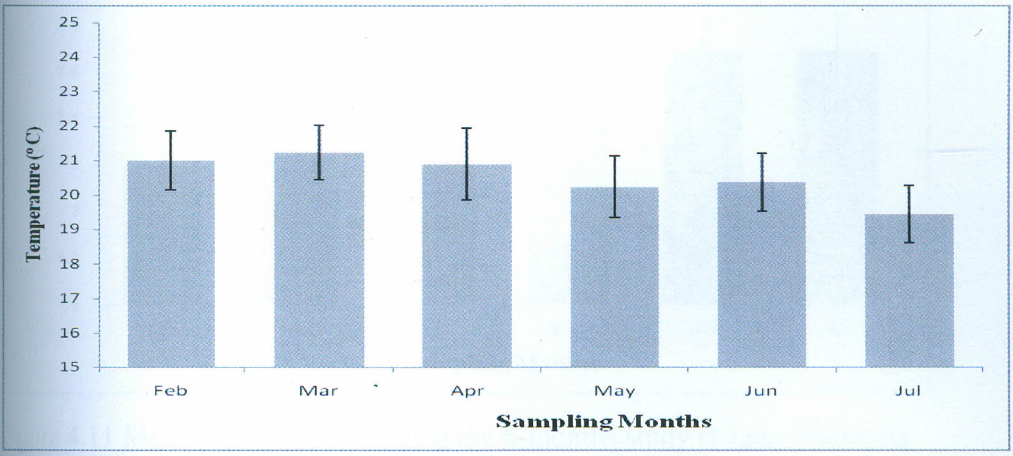


Figure 4.9 Mean temperature variations during the 6-months study at Lake Naivasha

The results on mean water temperature revealed that there was no temporal variation among the sampling months as shown in figure 4.9.

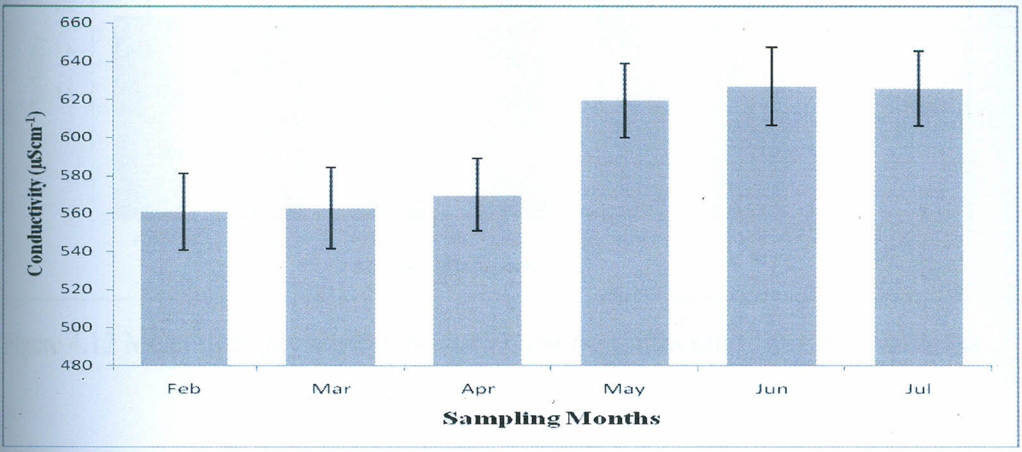


Figure 4.10 Mean conductivity variations during the 6-months study at Lake Naivasha

The results on mean conductivity revealed that there was temporal variation among the sampling months as shown in figure 4.10.

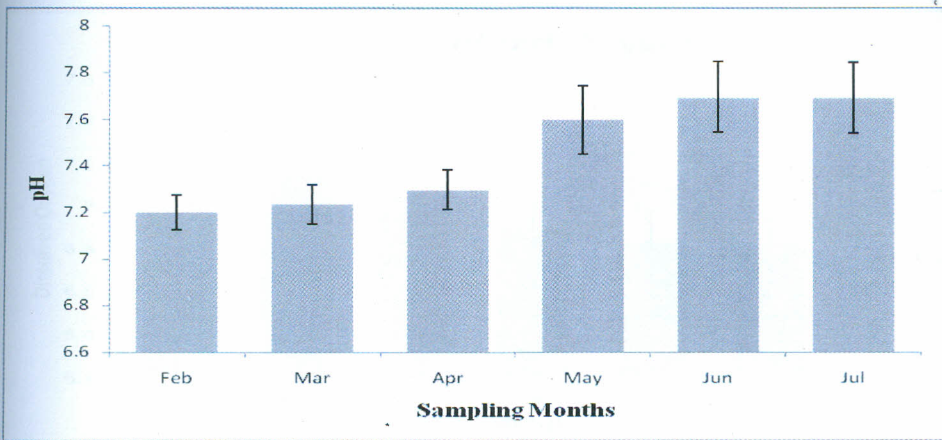


Figure 4.11 Mean pH varaitions during the 6-months study at Lake Naivasha

The results on mean pH revealed that there was temporal variation among the sampling months as shown in figure 4.11.

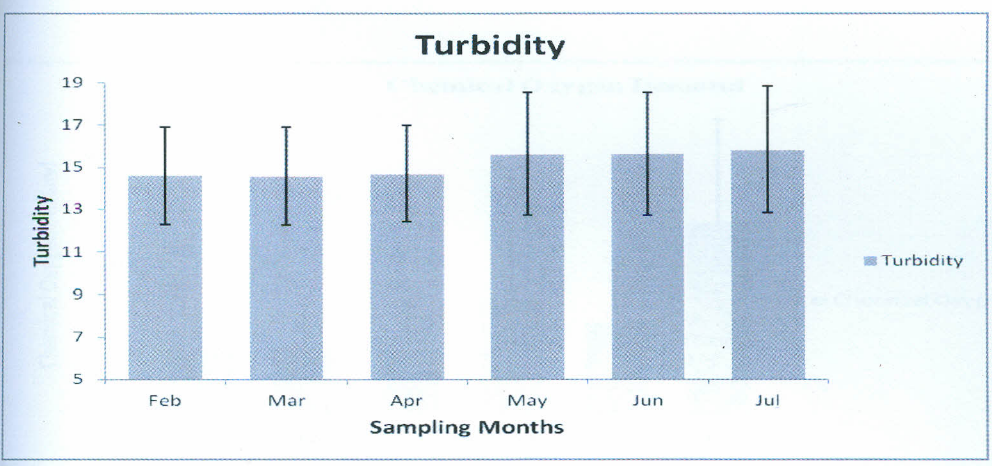


Figure 4.12 Mean turbidity variations during the 6-months study at Lake Naivasha

The results on mean turbidity revealed that there was no temporal variation among the sampling months as shown in figure 4.12.

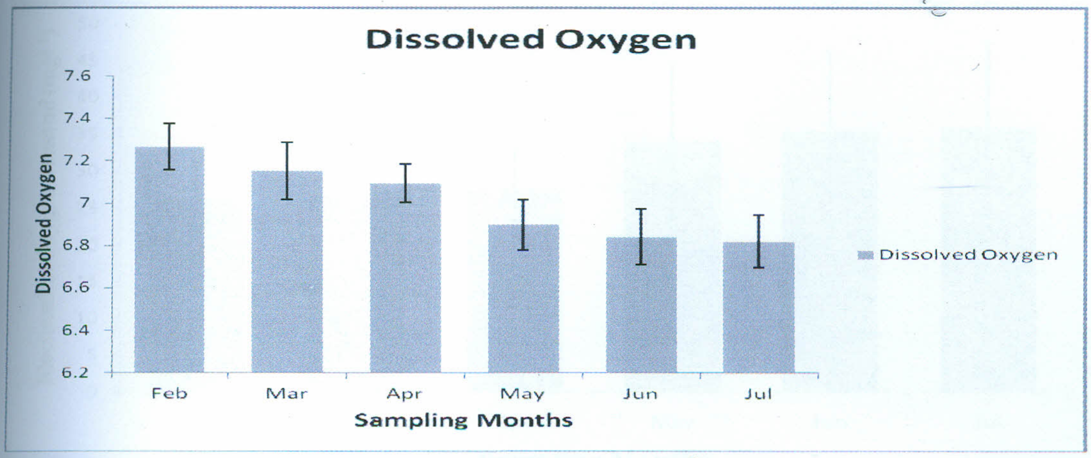


Figure 4.13 Mean Dissolved Oxygen variations during the 6-months study at Lake Naivasha

The results on mean Dissolved Oxygen revealed that there was temporal variation among the sampling months as shown in figure 4.13.

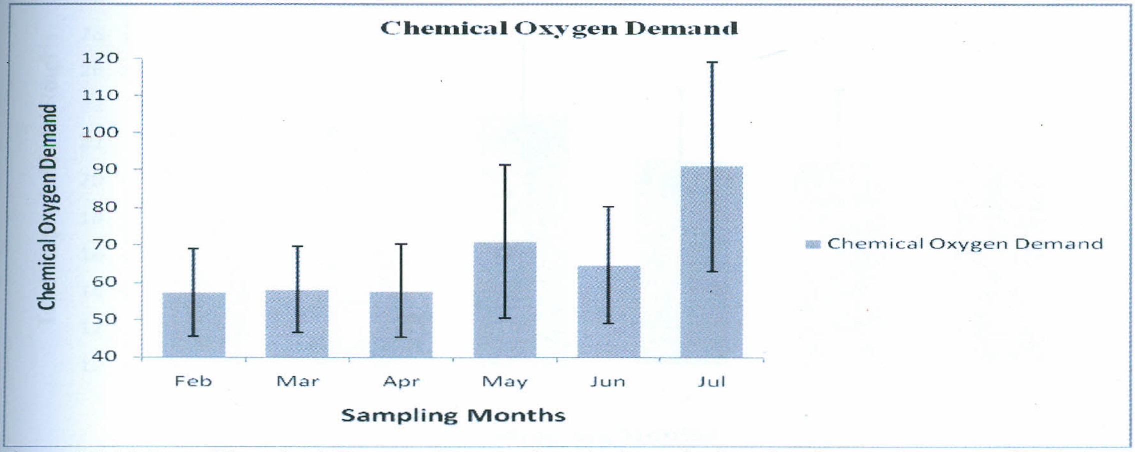


Figure 4.14 Mean Chemical Oxygen Demand variations during the 6-months study the Lake

The results on mean Chemical Oxygen Demand revealed that there was no temporal variation among the sampling months as shown in figure 4.14.

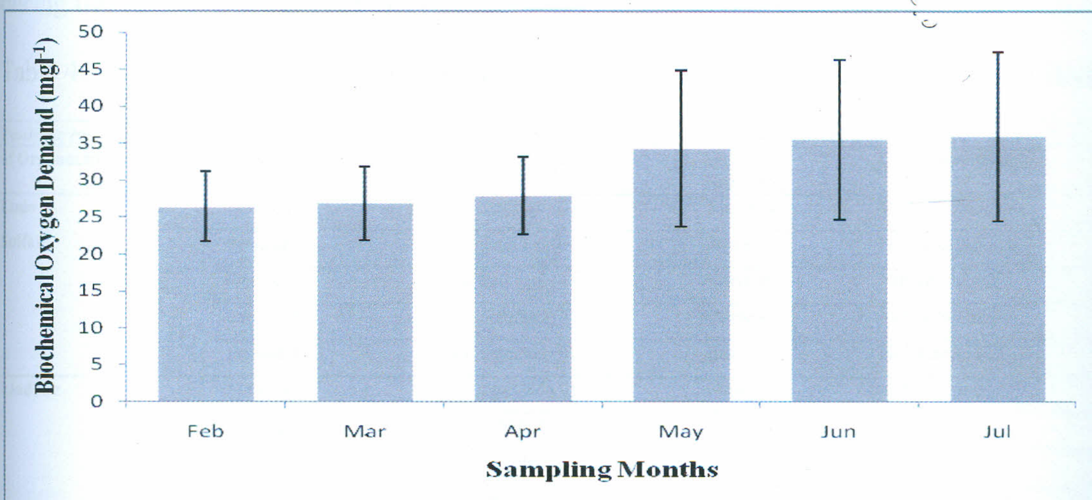

Figure 4.15 Mean Biochemical Oxygen Demand variation during the 6-months study the Lake

The results on mean Biochemical Oxygen Demand revealed that there was no temporal variation among the sampling months as shown in figure 4.15.

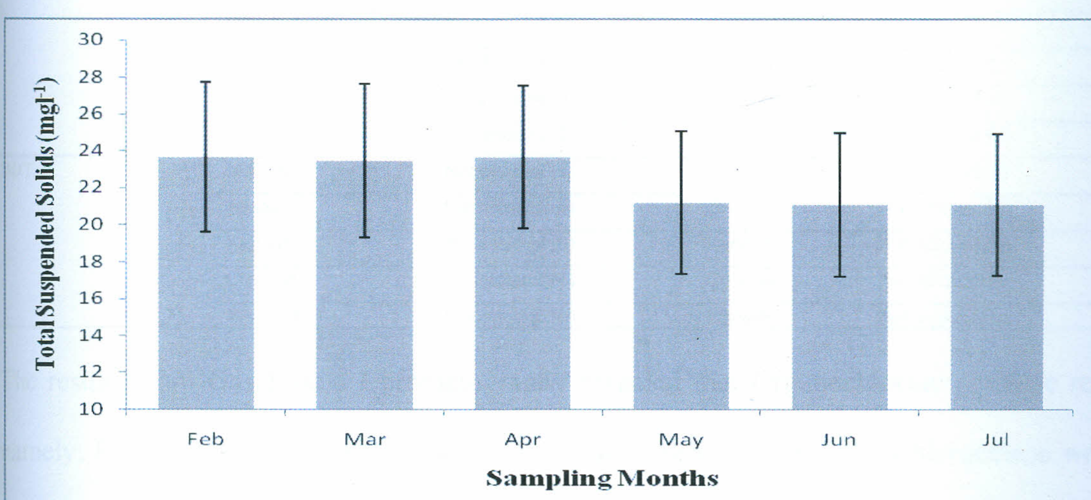

Figure 4.16 Mean Total Suspended Solids variations during the 6-months study at Lake Naivasha

The results on mean Total Suspended Solids revealed that there was no temporal variation among the sampling months as shown in figure 4.16.

## 4.3 The status of Organochlorine and Organophosphate in Lake Naivasha

The results of Organochlorine pesticide residues within the five sampling sites in Lake Naivasha during the 6 months study (February to July 2011) as shown in table 4.7.

Table 4.7 Status of Organochlorine pesticide residues in water within shores of Lake Naivasha

| Pesticide residues | Wet season | | Dry season | |
|---|---|---|---|---|
| of Organochlorine | sites | Concentration ppb | Dry Season | Concentration ppb |
| Endo Sulfan | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsemere | Not detected (0) |
| Lindane | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsemere | Not detected (0) |
| Aldrin | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsemere | Not detected (0) |
| Dieldrin | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsemere | Not detected (0) |
| DDT | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsemere | Not detected (0) |

The results from Gas Liquid Chromatography revealed that Organochlorine pesticide residues namely: Endosulfan ,Lindane, Aldrin , Dieldrin and Dichlorodiphenyl-trichloroethene were not detected in water samples across the sampling sites throughout the 6 months study duration.

The results of Organophosphate pesticide residues within the five sampling sites in Lake Naivasha during the 6-months study (February to July 2011) as shown in table 4.8.

Table 4.8 Status of Organophosphate pesticide residues in water within shores of Lake Naivasha

| Pesticide residues | Wet season | | Dry season | |
|---|---|---|---|---|
| of Organophosphate | sites | Concentration ppb | sites | Concentration ppb |
| Nemacur | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsamere | Not detected (0) |
| Orthene | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsamere | Not detected (0) |
| Durban | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsamere | Not detected (0) |
| Diazol | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsamere | Not detected (0) |
| Fenitrothion | Malewa | Not detected (0) | Malewa | Not detected (0) |
| | Sewage | Not detected (0) | Sewage | Not detected (0) |
| | Karuturi | Not detected (0) | Karuturi | Not detected (0) |
| | Crescent | Not detected (0) | Crescent | Not detected (0) |
| | Elsamere | Not detected (0) | Elsamere | Not detected (0) |

The results from Gas Liquid Chromatography revealed that Organophophate pesticide residues namely: Nemacur, Orthene, Durban, Diazol and Fenitrothion were not detected in water samples across the sampling sites during the 6-months study duration

### 4.4 Water birds abundance and distribution in Lake Naivasha

The water birds were counted across the five sampling sites off the shores of Lake Naivasha over the 6-months study period i.e. between the months of February to July, 2011. A total of 16,333 water birds were recorded as categorised namely: Hooked, Stout and spear, Long and stout and Flat and hooked.

#### 4.4.1 Spatial distribution of water birds

The results of the water bird numbers showing the mean and SD of variables counted in Lake Naivasha at different sites during a 6-month study (February to July, 2011) has shown in table 4.9.

Table 4.9. Water bird numbers (Mean±SD) at different sampling sites of Lake Naivasha

| Groups | Elsamere | Crescent | Karuturi | Sewage | Malewa | Overall mean |
|---|---|---|---|---|---|---|
| **Hooked** | 200.67±13.09$^{BC}$ | 227.33±11.13$^{A}$ | 213.33±12.79$^{AB}$ | 187.83±17.70$^{CD}$ | 180±14.0$^{D}$ | **201.83** |
| **Stout and spear** | 204.33±18.22$^{A}$ | 221.0±16.44$^{A}$ | 196.33±18.22$^{BC}$ | 174.33±17.13$^{C}$ | 189.67±18.84$^{BC}$ | **197.13** |
| **Long and stout** | 87.5±47.42$^{B}$ | 112.00±9.69$^{A}$ | 80.50±11.47$^{B}$ | 65.50±11.47$^{C}$ | 74.83±11.04$^{BC}$ | **84.07** |
| **Flat and hooked** | 62.17±9.99$^{B}$ | 66.83±8.30$^{B}$ | 56.33±10.15$^{B}$ | 81.33±10.15$^{A}$ | 40.3310.15$^{C}$ | **61.40** |

*Means with different superscripts in the same row are significantly different at P<0.05. (Data analyzed by Duncan's Multiple Range Test).

Hooked beaked birds mean density within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4,29)}=11.28, p<0.001$). Duncan Multiple Range Test (DMTR) established that Crescent Island Lagoon had the highest mean density (227.3) while River Malewa had the lowest mean (180.0). It further established that the mean bird density along the shores of Crescent Island Lagoon and Karuturi Flower Farms had no significant difference; Karuturi Flower Farms and Elsamere Conservation Centre had no significant difference; Elsamere Conservation Centre and Sewage Inflow had no significant difference. In addition, Sewage Inflow and River Malewa had no significant difference.

Stout and spear beaked birds mean density within the shores of Lake Naivasha varied significantly between the sampling sites (one-way ANOVA, $F_{(4,29)}=5.68, p=0.002$). Duncan Multiple Range Test (DMTR) established that within the shore of Crescent Island Lagoon had the highest mean density (221.0) while Sewage Inflow had the lowest mean (174.33). It further established that the mean density for Stout and spear birds within the shores of Crescent Island Lagoon and Elsamere Conservation Centre had no significant difference; Elsamere Conservation Centre, Karuturi Flower Farms and River Malewa had no significant difference and Karuturi Flower Farms, Sewage Inflow and River Malewa had no significant difference.

Long and stout beaked bird density within the shores of Lake Naivasha varied significantly between the sampling (one-way ANOVA, $F_{(4,29)}=15.16, p<0.001$). Duncan Multiple Range Test (DMTR) established that within the shore of Crescent Island Lagoon had the highest mean bird density (112.0) while Sewage Inflow had the lowest mean (65.5). It further established that the mean bird density within the shore of Crescent Island Lagoon was significantly different from the rest and that Elsamere Conservation Centre, Karuturi Flower farms and River Malewa had no significant difference, however, River Malewa and Sewage Inflow were not significantly different.

There was a significant difference in the mean density for Flat and hooked birds between the sampling sites ($F_{(4,29)}=14.08$, $p<0.001$). Duncan Multiple Range Test (DMTR) established that Sewage had the highest mean density for Flat and hooked birds (81.3) while River Malewa had the lowest mean (40.3). It further established that the mean density in sites: Crescent Island Lagoon, Elsamere Conservation Centre and Karuturi Flower farms had no significant difference. The remaining sites were significantly different.

In overall, the mean bird density along the shores of Lake Naivasha varied significantly among the sampling sites (one-way ANOVA, $F_{(4,29)}=6.66$, $p=0.001$). Duncan Multiple Range Test (DMTR) established that Crescent Island Lagoon had the highest mean bird density (627.17) while River Malewa had the lowest mean (484.83). It further established that the mean bird density within the shores of Elsamere Conservation Centre, Karuturi Flower Farms and Sewage Inflow had no significant difference.

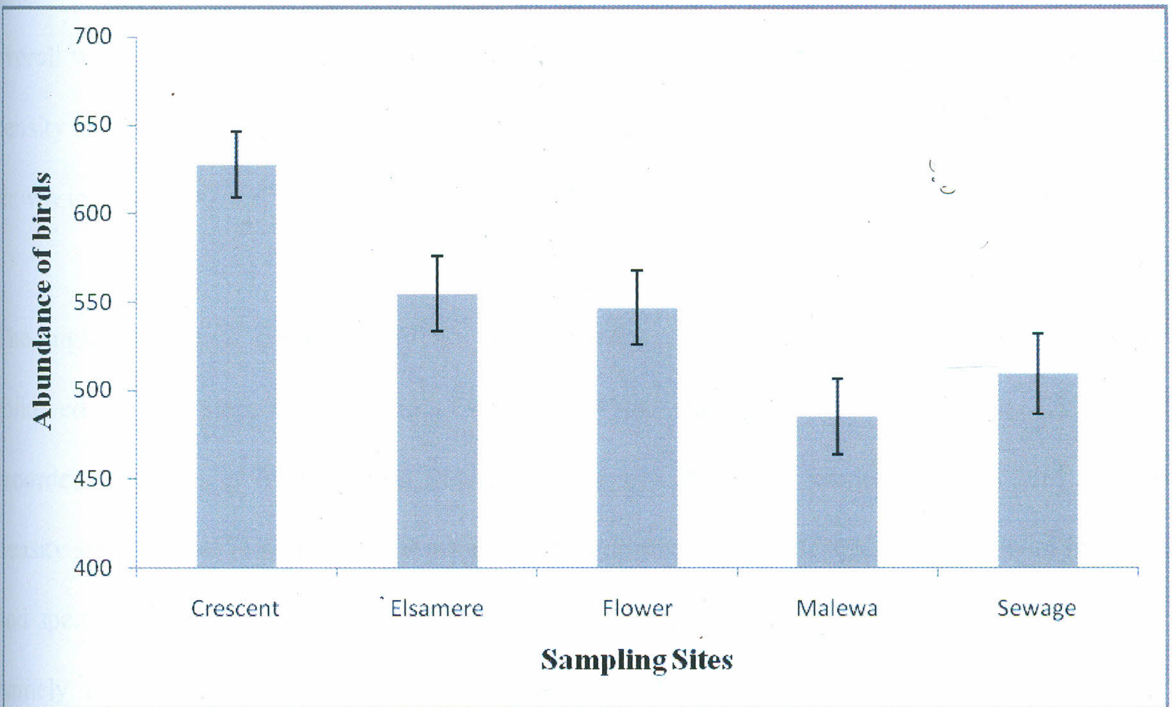

Figure 4.17 Overall water bird density variations at different sampling sites

The results on spatial distribution and water bird relative density reveal that there were variations in water bird numbers among the sampling sites during the 6-months study as shown in figure 4.17. These results had put into consideration the overall of the entire water bird as categorized namely: Stout and spear Hooked, Stout and long and lastly, Flat and hooked. It was imperative to note that Crescent Island Lagoon had the highest counts closely follow by both Elsamere Conservation Centre and Karuturi Flower farm Inflow, thereafter Sewage Inflow and lastly River Malewa had lowest relatively counts (Figure 4.17). The study however noted that despite these observations each sampling site had substantial counts of the water birds as categorised. These were good signs of the Lake being habitable and attracting varieties of water birds despite the high levels of anthropogenic activities ongoing in the Lake's vicinity.

The relative densities (RD) were calculated based on the grand total 16,333 (Table 4.10) of overall water birds counted. The results of the water bird numbers showing counts and relative density at different sites in Lake Naivasha during the 6-month study (February to July, 2011) has shown in table 4.10.

The highest relative density (23.0%) was recorded along Crescent Island Lagoon closely followed by Elsamere Conservation Centre (20.4%). The least relative density (17.8%) was recorded along River Malewa and Sewage Inflow (18.7%). The results on water bird relative density showed that Hooked shaped group of birds dominating (37.1%) closely followed by Stout and spear (36.3%) as shown in table 4.10. Some of the birds identified in these two groups were namely: Long tailed, Great cormorant, Fish eagle, Pied kingfisher, Watch back and Heron.

Table 4.10 Relative density (RD) of water bird at different sampling sites of Lake Naivasha

| Groups | Elsamere | | Crescent | | Karuturi | | Sewage | | Malewa | | Overall total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Popn | RD (%) | Popn | RD (%) | Popn | RD (%) | Popn | RD (%) | Popn | RD (%) | Popn | RD (%) |
| Hooked | 1204 | 7.4 | 1364 | 8.4 | 1280 | 7.8 | 1127 | 6.9 | 1080 | 6.6 | **6055** | **37.1** |
| Stout and Spear | 1226 | 7.5 | 1326 | 8.1 | 1178 | 7.2 | 1046 | 6.4 | 1138 | 7.0 | **5914** | **36.3** |
| Long and stout | 525 | 3.2 | 672 | 4.1 | 483 | 3.0 | 393 | 2.4 | 449 | 2.8 | **2522** | **15.4** |
| Flat and hooked | 373 | 2.3 | 401 | 2.5 | 338 | 2.1 | 488 | 3.0 | 242 | 1.5 | **1842** | **11.3** |
| Overall Total | **3328** | **20.4** | **3763** | **23** | **3279** | **20.1** | **3054** | **18.7** | **2909** | **17.8** | **16333** | **100** |

### 4.4.2 Temporal abundance and distribution water birds in Lake Naivasha

The results of the water bird showing the mean and SD of variables counts in Lake Naivasha) at different months during a 6-month study (February to July, 2011 has shown in table 4.11.

Table 4 11 Bird numbers (Mean±SD) during the 6-months study in Lake Naivasha

| Groups | Feb | March | April | May | June | July | Overall mean |
|---|---|---|---|---|---|---|---|
| Stout and hooked | 181.80±18.63$^{B}$ | 185.40±18.19$^{B}$ | 192.0±17.13$^{B}$ | 193.20±17.36$^{B}$ | 200.0±17.01$^{B}$ | 230.40±17.34$^{A}$ | **197.13** |
| hooked | 187.40±21.65$^{B}$ | 191.20±20.55$^{B}$ | 195.00±20.64$^{B}$ | 205.0±17.78A$^{B}$ | 207.8±17.44$^{AB}$ | 224.60±17.11$^{A}$ | **201.83** |
| Long and stout | 73.20±18.49$^{B}$ | 76.00±18.08$^{B}$ | 78.00±17.68$^{AB}$ | 83.20±17.56A$^{B}$ | 90.20±17.02$^{AB}$ | 103.00±16.63$^{A}$ | **83.93** |
| Flat and hooked | 49.60±15.24$^{B}$ | 54.40±15.13$^{AB}$ | 57.20±15.02$^{AB}$ | 62.00±14.93A$^{B}$ | 69.60±14.84$^{AB}$ | 75.60±14.79$^{A}$ | **61.4** |
| Overall Mean | 490.00±71.82$^{B}$ | 507.0±71.66$^{B}$ | 523.0±73.19$^{B}$ | 543.40±73.70$^{B}$ | 567.6±72.15$^{AB}$ | 633.6±72.15$^{A}$ | **544.43** |

*Means with different superscripts in the same row are significantly different at $P<0.05$. (Data analyzed by Duncan's Multiple Range Test).

Hooked beaked birds mean density within the shores of Lake Naivasha showed no significant between the sampling months (one-way ANOVA, $F_{(5,29)}=2.51, p=0.058$). Duncan Multiple Range Test (DMTR) established that July had the highest mean density (224.6) while Feb had the lowest mean (187.4).

Stout and spear beaked birds mean density within the shores of Lake Naivasha showed no significant between the sampling months (one-way ANOVA, $F_{(5,29)}=4.93, p=0.003$). Duncan Multiple Range Test (DMTR) established that July had the highest mean density (230.4) while February had the lowest mean (181.8). It further established that the mean density for Stout and spear in July was significantly different from the other months and that all the other months were not significantly different.

Long and stout beaked birds mean density within the shores of Lake Naivasha showed no significant between the sampling months (one-way ANOVA, $F_{(5,29)}=1.96, p=0.121$). Duncan Multiple Range Test (DMTR) established that July had the highest mean density (103.0) while Feb had the lowest mean (73.2).

Flat and hooked beaked birds mean density within the shores of Lake Naivasha showed no significant between the sampling months (one-way ANOVA, $F_{(5,29)}=2.11, p=0.099$). Duncan Multiple Range Test (DMTR) established that July had the highest mean density (75.6) while February had the lowest mean (49.6).

In overall, the mean bird density within the shores of Lake Naivasha showed no significant difference between the sampling months (one-way ANOVA, $F_{(5,29)}=4.41, p=0.006$). Duncan Multiple Range Test (DMTR) established that July had the highest mean bird density (633.6) while Feb had the lowest mean (492.0). It further established that the mean bird density in July and June were not significantly different and that February, March, April and May were also not significantly different as shown in figure 4.18.

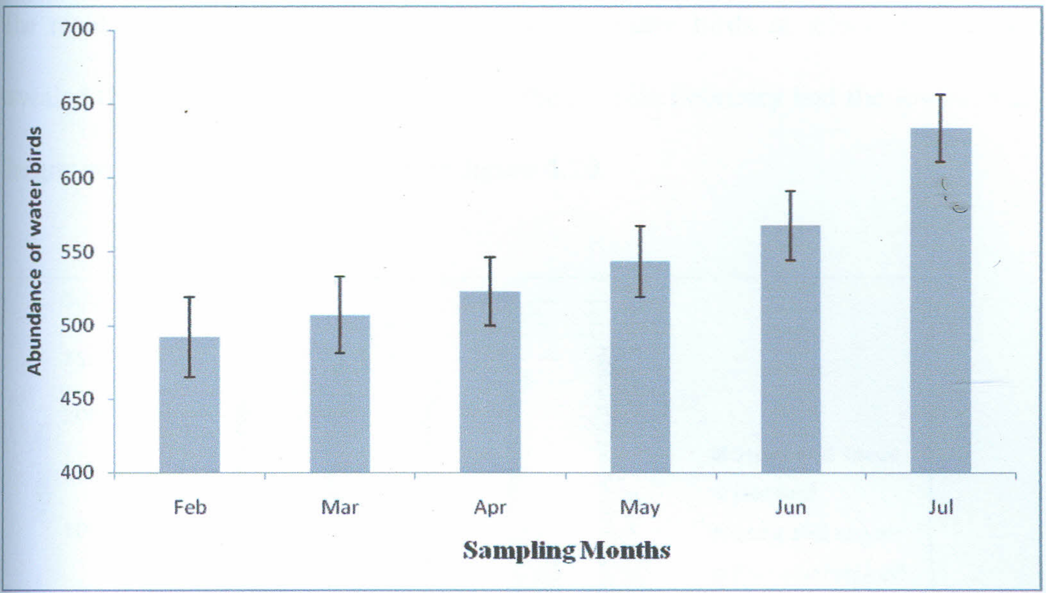

Figure 4.18. Overall water bird density variations during the 6-months study of the Lake

The results on water bird density revealed that there was temporal variation during the 6-months study duration. The study noted that there was steady growth of the water birds among the sampling months.

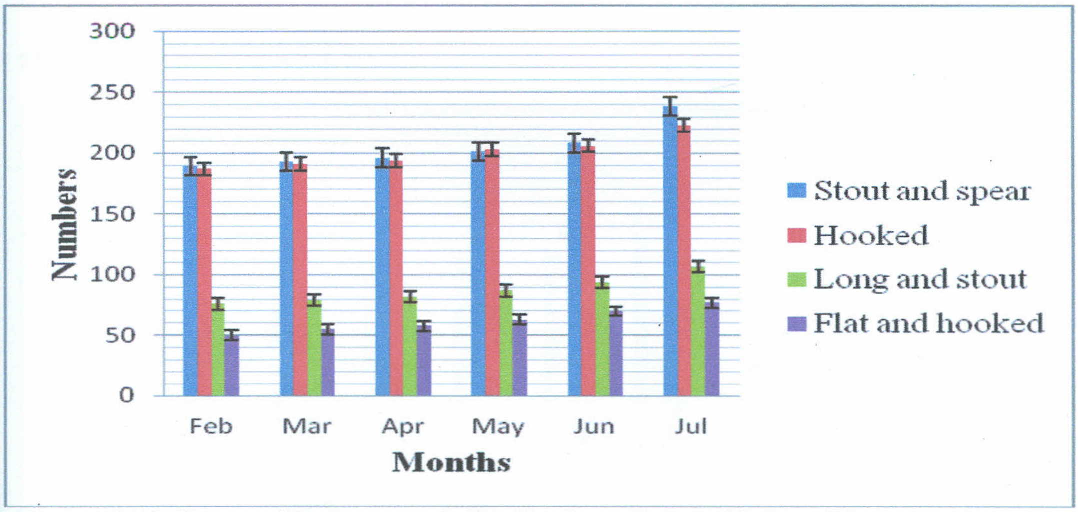

Figure 4.19 Shows abundance and distribution of water birds at Elsamere

The results on abundance and distribution of water birds at Elsamere Conservation Centre revealed that the month of July had the highest while February had the lowest water bird among the groups of water birds as shown in figure 4.20.

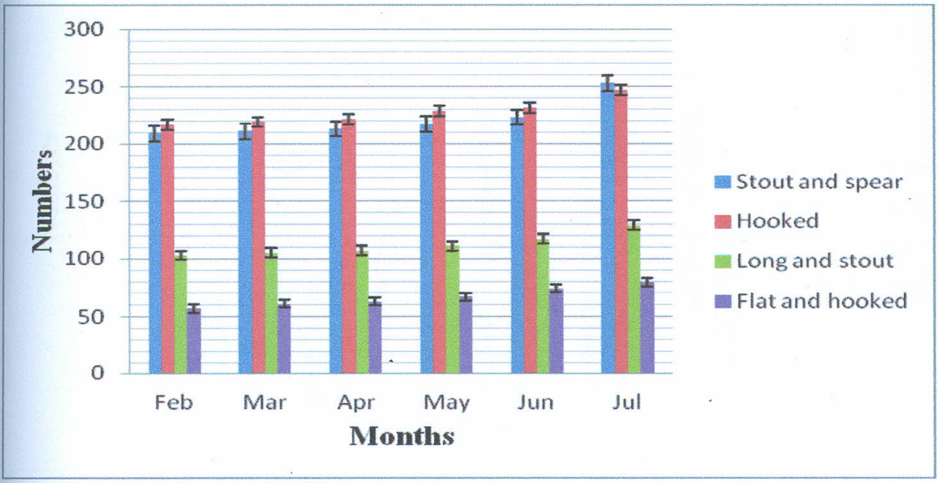


Figure 4.20 Shows abundance and distribution of water birds at Crescent

The results on abundance and distribution of water birds at Crescent Island Lagoon revealed that the month of July had the highest water bird while the lowest month of February among the groups of water birds as figure 4.20.

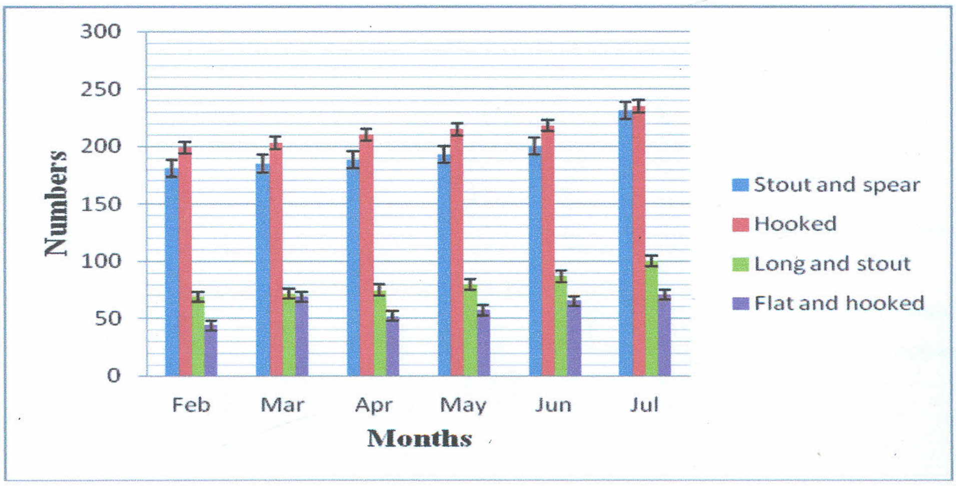


Figure 4.21 shows abundance and distribution of water birds at Karituri

The results on abundance and distribution of water birds at Karituri Flower Farms revealed that the month of July had the highest while February had lowest water bird among the groups of water birds as shown in figure 4.21.

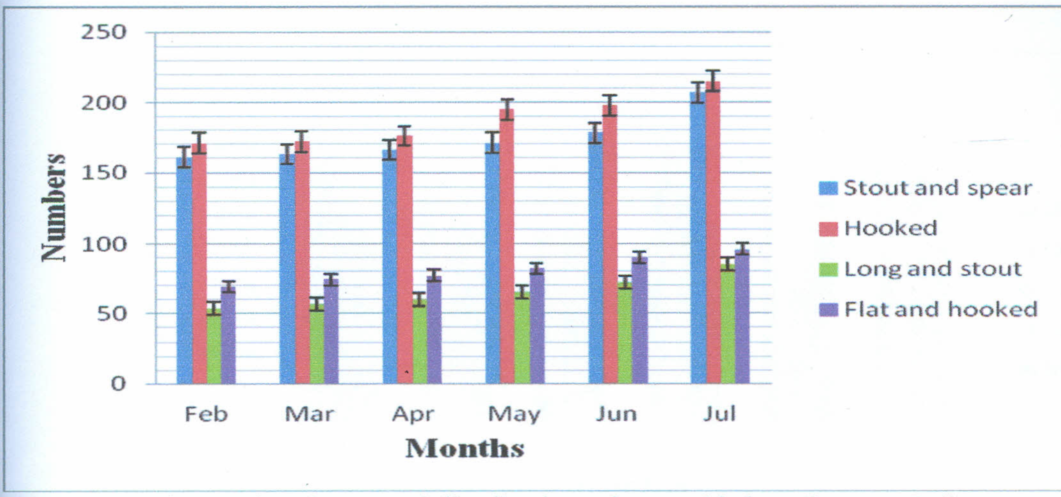


Figure 4.22 Shows abundance and distribution of water birds at Sewage Inflow

The results on abundance and distribution of water birds at Sewage Inflow revealed that the month of July had the highest water bird across the groups of water birds while the month of February had the lowest as shown in figure 4.22.

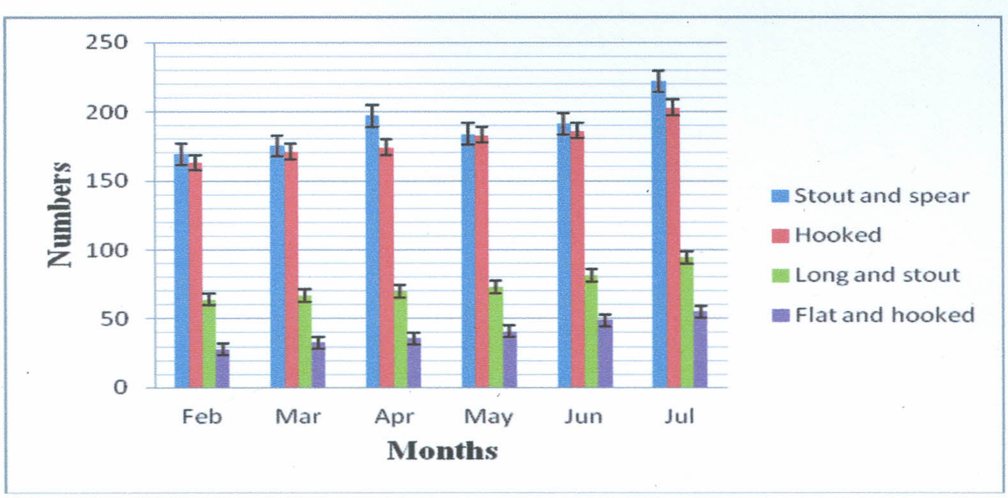


Figure 4.23 Shows abundance and distribution of water birds at River Malewa

The results on abundance and distribution of water birds at River Malewa revealed that the month of July had the highest water bird across the groups of water birds while the lowest was in the month of February as shown in figure 4.23.

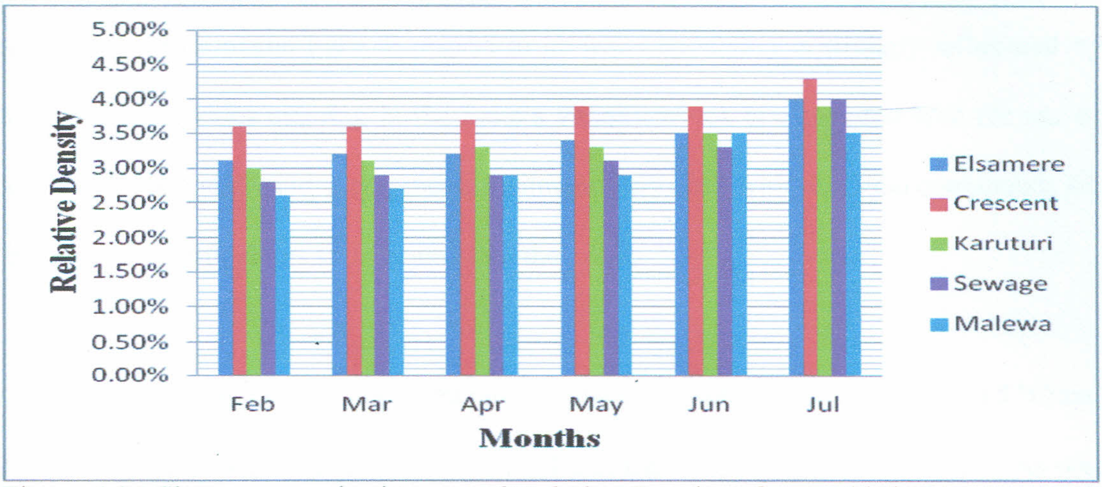


Figure 4.24 Show summarised temporal Relative Density of water birds

The results of the water bird showing the relative densities of counts in Lake Naivasha) at different months during a 6-month study (February to July, 2011) has shown in figure 4.24.

# CHAPTER FIVE

# 5.0 DISCUSSION

## 5.1 Water physico-chemical variables in Lake Naivasha

The water characteristic of the Lake in respect to its water suitability is strongly influenced by the anthropogenic activities ongoing in the Lake's vicinity which is associated with the use of pesticides, soil erosion and wind occurrences. Sediments adsorbed with chemical compounds are carried by surface run off, rivers and streams into the Lake.

In overall, result revealed warm water temperatures during the study with a mean of 20.5 °C and standard deviation of ±3.4 (Table 4.1). It was noted that the temperature of Lake Naivasha was low in the morning and increases in the course of the day as the heat from the sun intensifies. The low temperature of the Lake in the morning was attributed to heat loss from the Lake by specific conduction to the air (Verschuren, 1999) which was enhanced by evaporation. Therefore, to avoid high disparities, water sample for temperature measurements were prepared and measured in situ at mid day.

The results revealed high water temperatures (Table 4.1) which were attributed to the ambient air temperature and the water heating at mid day when the solar radiation is at its maximum (Bootsma and Hecky, 1993). Furthermore, solar radiation is high throughout the year in Kenya and in most countries in the tropics (Lalah *et al.*, 2001). High water temperatures were recorded in the month of March while low temperatures were in the month of July (Table 4.6). This was an indication that the Lake was affected by seasonal climatic variation where by the wet season was accompanied by poor mixing of surface and sub-surface waters (Waltson, 2010). This agrees with Campbell *et al.*, (2003) who noted that the current water temperatures were rising.

In overall, results revealed that the Lake experienced moderate water conductivity with a mean of 594.1 $\mu Scm^{-1}$ and standard deviation of ±81 (Table 4.1). It also revealed that the off shore of River Malewa Inflow had the highest conductivity (Table 4.5). This was attributed to clearance of the original forest, particularly the papyrus swamp in the northern delta of the River Malewa's Inflow (North Swamp) (Gaudet and Muthuri, 1981, Kitaka *et al.*, (2002) which served as a filter retaining sediment from upstream during period of rains. As such, the Inflow could contain a large amount of sediments and conductivity could change very rapidly in a few hours (Kitaka *et al.*, 2002).The results revealed moderate water conductivity; however, there was an increase from initiation of the study in the month of February towards its completion in July (Table 4.6). The month of February had a low conductivity in comparison to the month of June (Table 4.6). This was attributed to season variation as weather changed from dry to wet season. The study established a significant change in mean conductivity from 564.4 $\mu S\ cm^{-1}$ (Table 4.3) to 623.8 $\mu S\ cm^{-1}$ (Table 4.4) with seasonal variation. The result revealed that current range of 447-738 $\mu S\ cm^{-1}$ (Table 4.1). This was attributed to surface run off with sediments, the drainage from irrigation, chemical residue and the Lake's water level fluctuation which had a strong influence on its water quality and its ecological biodiversity (Harper *et al.*, 1990).

In overall, results revealed moderate water pH values with a mean of 7.45 and standard deviation of ±0.5 (Table 4.1). The Lake recorded moderate pH range of 6.71-8.94 (Table 4.1). It was noted Harper *et al.,* (1990) who also recorded a pH range of 7.7-8.5. However, it was noted that the values of pH were slightly affected by seasonality. The month of June recorded relatively high pH as compared to the month of February (Table 4.6). This was attributed to the surface run off which carries with ions minerals into the shores of the Lake.

In overall, the results revealed moderate turbidity with a mean of 15.15 NTU and standard deviation of ±9.93 (Table 4.1). The results revealed moderate level of turbidity. The values were within the permissible levels according to World Health Organisation and Kenya Bureau of Standards recommendation recommendations (Table 4.2; Appendices I, II, III and IV). However, the results revealed significant deviation from the water samples collected within the shores of River Malewa and Karuturi Flower (Table 4.5) Farms where relatively high relative to other sampling sites. This was attributed to the change of land use and erosion which contributed to silt. The results revealed higher turbidity level at the Elsamere Conservation Centre (Table 4.5) which was attributed to wind and human perturbation. Furthermore, this site had high silt, which is easily re-suspended in the water column. Lind *et al*., (1992) who noted that the extent of re-suspension is a function of depth, fetch, wind velocity and nature of sediment, which include sizes and densities. It was noted that change in seasonality had some influence in the level of turbidity attributed to the effects of seasonal climatic patterns and seasonal variation. The month of July experienced relatively high turbidity concentrations compared to the month of March (Table 4.6). The wet season was accompanied by strong water currents and increased air movement (Waltson, 2010). Furthermore, intensive land use and soil erosion in the catchment area which was enhanced during the wet season due to high sediment load according to Kitaka *et al*., (2002).

In overall, the results high Dissolved Oxygen in the water with a mean of 7.01 $mgl^{-1}$ and standard deviation of ±0.48 (Table 4.1) which was attributed to the Lake's altitude (1884 m.a.s.l) (Harper, 1993). High altitude promoted the dissolution of oxygen in water but, this is limited to about 11 mg/l as this was a function of pressure (Bootsma and Hecky, 1993). The results further revealed that Elsamere Conservation Centre and Crescent Island Lagoon had relatively higher concentration of Dissolved Oxygen relative to other sites (Table 4.5). This result was attributed to their pristine surroundings. The results also revealed that Dissolved Oxygen levels in February were slightly higher to July (Table 4.6) which was attributed to season variation which was associated to the decomposition of microphytes which inhabits the shores during the wet season. This leads to high algae growth which consumes by far a large volume of oxygen than consumed by both animals and plants (Wetzel, 1983).

In overall, the results revealed moderate Chemical Oxygen Demand in water of Lake Naivasha with a mean of 66.5 $mgl^{-1}$ and the standard deviation of ±67.3 (Table 4.1). The values were within the permissible levels according to World Health Organisation and Kenya Bureau of Standards recommendation (Table 4.2; Appendices I, II, III and IV). However, the study noted some deviation from the water samples collected within the shores of Sewage Inflow and Karuturi Flower Farms (Table 4.5) which were indications of significant level of organic and inorganic matter entering the Lake through the two sites. The results revealed moderate Chemical Oxygen Demand with a gradual increase their levels with seasonal variation. It was imperative to note that the month of February recorded low concentration of Chemical Oxygen Demand as compared to the month of July (Table 4.6). This was attributed to surface run off which carries with it organic and inorganic material entering the Lake during wet season (Harper *et al.*, 1990).

The results revealed moderate Biochemical Oxygen Demand in the water with a mean of 31.1 $mgl^{-1}$ and standard deviation of ±32.3 (Table 4.1). The values were within the permissible levels according to World Health Organisation and Kenya Bureau of Standards recommendation (Table 4.2; Appendices I, II, III and IV). However, it was noted that there were fluctuations from the water samples collected within shore of the Sewage Inflow and Karuturi Flower Farms (Table 4.5) which were attributed to significant quantities of impurities entering the Lake through these two sampling sites.

In overall, results revealed moderate levels of Total Suspended Solid in the water with a mean of 22.4 $mgl^{-1}$ and standard deviation of ±14.9 (Table 4.1). The values were within the permissible levels according to World Health Organisation and Kenya Bureau of Standards recommendation (Table 4.2; Appendices I, II, III and IV). However, the study revealed some fluctuations from the water samples prepared within the shores of River Malewa and Karuturi Flower Farms (Table 4.5) were relatively high concentrations of Total Suspended Solids were observed.

The results revealed that water physico-chemical variables were within the limit of maximum level permissible according to World Health Organisation and Kenya Bureau of Standards recommendation (Table 4.1; Appendices I, II, III and IV). It was noted that the Lake experienced rise in water levels to the extent of overflowing its fringes especially in the months of May, June and July. It was also noted that some flower farms had already adopted new technologies that use very little water including installation of water meter and drip irrigation system through the influence of Lake Naivasha Riparian Association. Similarly, Watson, (2010) also noted a rise in the Lake's water levels.

### 5.2 The status of Organochlorine (OC) and Organophosphate (OP) pesticides

Rivers, streams and surface run off are the main source of Lake Naivasha (Bennun *et al*., 2002). The adjacent areas to the rivers is characterised by intensified agricultural activities associated with sediments and chemical residue reaching the Lake (Kitaka *et al*., 2002). Seasonal variation did have much effect on the discharge pattern. This was attributed to non reliance on rain fed agriculture since flowers were produced in green houses under irrigation. Therefore, their discharges were continuous throughout the year.

The results revealed that Organochlorine namely: a) Endosulfan b) Lindane c) Aldrin d) Dieldrin e) Dichlorodiphenyl-trichloroethene (Table 4.7) were not detected in the water samples prepared. This was attributed to increased rate of degradation at the tropic (Iwata *et al*, 1994). Apparently the half-life of Organochlorine is relatively short in the tropic (Iwata *et al*, 1994). Farmer *et al*., (1971) noted that the concentration of Lindane and Dieldrine rapidly degrade an increase in temperature increases votalisation four fold.

The results revealed that Organophosphate (OP) namely: a) Nemacur b) Orthene c) Durban d) Diazol and e) Fenitrothion Organophophate (Table 4.8) not detected in the water samples prepared which was attributed to their short half-life. This was consistent with other studies (Lalah and Wandiga, 1996; Gitahi *et al*., 2002; Cremlyn, 1979) who also noted that

Organophophate pesticides remain active in the environment for shorter time. In agreement also were, Lalah and Wandiga (1996) who noted that Organophophate pesticides were below the detection limits in Lake Naivasha. Their photolytic process is aided water (Lalah, 1993). Furthermore, their low deposition rate due to their high solubility in water and potential hydrolysis degradation (Ji-Zhong *et al*, 2012) making it difficult to detect them unless samples were taken immediately after their application

Most of the cut flowers are produced in Lake Naivasha targets European markets. The strict international trade regulations with respect to compliance to maximum pesticide residual level requirement has left farmers with no option but to adopt environmentally safe options in order to sustain their export markets. Flower farmers have to comply with the recommendation of pesticide-free fresh produce in order maintain their international clientele who have become more aware of environmental and ethical matters following recent inclusion of cut flowers in the same ecological and health standards as edible vegetables. Following this development, the Kenya Flower Council, the main industry association had established codes of conduct covering working conditions, including pesticide exposure, for its members. They, along with trade unions, were putting pressure on the global floriculture industry to develop and conform to codes of conduct for workers' health and safety (FAO, 2010).

Following these developments, it was noted that there were concerns regarding the potential economic effects of these pesticides. It was noted that there were public awareness campaigns ongoing following the ban of production and usage of Organochlorine pesticide compounds in most developed country (U.S. Geological Survey, 2005). There was high level of awareness of the adverse effects of these pesticides among stakeholders (Gitahi, 2002). Similarly, Getenga *et al*., (2000) agreed that advocacy on appropriate use of pesticides based on recommendation to mitigate their adverse impact on the environment had been ongoing. For instance, Lake Naivasha Riparian Association (LNRA, 1999) a pioneer example of a local community was taking the lead, initiating major actions, and achieving results for the long-term conservation and wise use of wetlands. Through the Association, a management plan is in place at Lake Naivasha. The plan was officially adopted in 1997 and includes the concept of sustainable development, wise use of resources and voluntarily adopted sectoral codes of conduct.

It was noted that there was an outstanding demonstration of implementation of the two major objectives of the Ramsar Convention: conservation and wise use of wetlands for the well-being of local populations. It was noted that, Lake Naivasha Riparian Association (LNRA, 1999) in collaboration with the KWS, Naivasha Municipal Council, Fisheries Department, Naivasha Growers association, NEMA and others stakeholders had put in place long term Environmental Management Plan. It was also noted that Lake Naivasha Growers Management Plan had incorporated best management practices to reduce the use of synthetic organic pesticides. The plan had in place guidelines and regulations on the issues of usage, storage and disposal of pesticides. Environmental Management Systems with techniques aimed at reducing or eliminating contaminants at the point of generation.

The Ministry of Water through Water Resource Management Authority had embarked on Imarisha Lake Naivasha programme to monitor the Lake restoration plan. It was also noted that NEMA was more vigilant and involved in regular inspection on flower farms to stop any further emissions following the February, 2010 fish deaths. NEMA, through its environmental monitoring and compliance unit was enforcing the provisions of the second schedule of the Environmental Management and Coordination Act (EMCA, 1999) which requires that Environmental Impact Assessment (EIA) and Environmental Audits (EA) be carried out for large scale agricultural activities.

Furthermore, from the interview conducted during the study, one of the flower farm workers from Pest and Disease Control Unit agreed."We have excellent water and sewage treatment facilities here. We do not let chemicals flow into the Lake without treatment whatsoever. We are very conscious of our farming techniques," said James Owino, a worker at one of about 30 horticulture farms in Naivasha. Most of the flower farms have adopted the modern strategy of pest control, Integrated Pest Management (IPM) while reducing chemical pesticide use.

It was noted that there were ongoing monitoring programmes carried out with diverse stakeholders in the Lake and its environs according to Mavuti and Harper, (2005) who made similar observations. Following this development it was easier to determine with confidence the principal sources of pollutants and put in place measures to maintain their levels below the maximum acceptable levels in drinking water (WHO, 1984; CCME, 1991; GOK, 2006). Furthermore, appropriate use of pesticides based on recommendation is generally expected to cause little adverse impact on the environment (Getenga *et al*., 2000).

### 5.3 Water birds abundance and distribution along the shores of Lake Naivasha

The nature of impurities in the discharge released into the Lake could had influenced and restructured the Lake's ecology. According to Furness and Greenwood, (1993) the assessment of abundance and distribution of water birds was an independent way of monitoring aspect of environment pollution. Whereby increase in abundance was associated with disappearance of Organochlorine compounds (Iwata *et al.*, 1994) while the reduction in water birds numbers was an indication of underlying environmental problems (Bennum *et al.*, 2002).This was in agreement with Harper and Muchiri, (1986) who noted that the ecology of the Lake was ever changing. The prevailing environmental conditions played an important role in influencing the water bird numbers since birds are known to be responsive to changes taking place on this particular ecosystem (Henderson and Harper, 1992).

The results revealed an increase in water bird numbers from the initiation in the month of February to completion in July, 2011(Table 4.11). This agrees with Barasa *et al.*, (2006) whose survey showed an upward trend in water bird numbers relative to the years before. However, the results revealed that water birds were not confined to one particular site although their abundance varied.

In overall, the results revealed an increase in the water birds across the five sampling sites (Table 4.9). This was attributed to considerable ease in pressure in fish following net mesh-size regulations, particularly for the bass fishery (LNRA, 1999). Similarly, Njunguna, (2002) noted that the government had imposed a temporary ban on fishing in 2001. It was observed that water birds composition changes as conditions changes with some group relatively responding faster to the change. For instance, the fish eagle population in the Lake's riparian habitat had increased. This was attributed to the two year fish ban in the Lake according to Munir Virani-the Peregrine Fund, Kenya (Otieno *et al.*, 2004). It was also noted that the Lake and its environs supported diverse water bird community. These findings were in agreement with Clark *et al.*, (1989) report on abundance of waterfowl (around 35,000 individuals). Moreover, Harper *et al.*, (2002); Boar *et al.*, (2002) who noted that habitat biodiversity and abundance of water birds appear strongly linked to the fresh water status of the Lake.

The results revealed that Crescent Island Lagoon had the highest numbers of water birds (Tables 4.9 and 4.10). Similarly, a survey carried out by Earth watch, (August 1992), which noted that most birds were within the eastern shore, especially around the Crescent Island Lagoon. This was attributed to open and more expansive shoreline. In addition, the area had incorporated areas of flooded or floating vegetation with grassy shores around it making it easy for the water birds to access to the open areas behind the papyrus fringe where the wading birds.

The results revealed that mouth of River Malewa had the least numbers of water birds (Tables 4.9 and 4.10). This was attributed to continuous interference by human activities within its shorelines resulting to ecological changes witnessed especially on the northern off shores of the Lake. Otieno *et al.*, (2002) identified human pressure as the possible cause for the drop in previous numbers. Furthermore, the study noted that the site was inhabited with water birds mostly feeding on invertebrates, amphibians and microscopic algae which were most affected by any slight change in environment. For instance, the north was devoid of most natural vegetation while the remnants of the original forest exist only in small patches, and cultivation often extends right down to stream level (Kitaka *et al.*, 2002).

The results revealed a significant increase in the number of water birds within the shore of Karuturi Flower Farms (Tables 4.9 and 4.10). This was attributed to their high level of compliance following adoption of the Environmental Management Plan. It was noted that there was high level of community concerns regarding the potential effects of pesticides residue contamination on non target organisms Gitahi, (2002) also noted a similar observation among stakeholders.

Generally, the results revealed that piscivorous water birds especially the Hooked, Stout and spear and Long and stout shaped groups were increasing relatively faster in comparison to the Flat and hooked group (Table 4.9 and 4.10). This was attributed to the difference in feeding habits where by healthy fish population favoured especially Long tailes, Great cormorants, Fish eagles, Pied kingfisher, Watch back and Herms who were fish eaters. Moreover, following the introduction of exotic crayfish in 1970 (Harper et al., 2002) and common carp in 2001 (Brecht *et al.*, 2005). Nine years later, in 2010, common carp have increased in numbers and now accounting for over 90% of the mass of fish caught in the Lake associating it with the recovery of fish stocks (Daily Nation 15th February, 2010.).

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

Despite the dynamics of this ecosystem, it was noted that various interventions and implementation of conservation efforts in Lake Naivasha catchment area were yielding fruits. The study concluded that all of the water samples prepare and tested for water analysis were within the recommended compliance level of World Health Organisation and Kenya Bureau of Standards (Table 4.2; Appendices I, II, III and IV) with few disparities attributed to the differences in the nature of impurities discharged across five the sampling sites. Furthermore, concluding that the water bird numbers were increasing within the Lake's shores.

The study concluded that no Organochlorine and Organophosphate pesticide residues were detected in water (Tables 4.7 and 4.8). The study concluded that both Organochlorine and Organophosphate pesticide residues did not pose any significant threat in the waters of Lake Naivasha. These pesticides were neither environmental nor human health hazards in the water of Lake Naivasha. The study concluded that that measures put in place by the government and stakeholders were preventing further pollution of the Lake.

The study concluded that the water birds were increasing in numbers within the shores of Lake Naivasha (Table 4.11). It was further concluded that this was a reflection of environmental influence of water quality with respect to its water suitability as habitat for water birds. It was concluded that the water birds as bio-indicator were able to evaluate changes in biodiversity and ecology of this habitat.

The study concluded that water birds abundance and distribution appeared to be influenced by environmental changes as individual, group and community depending on their resilience or elasticity in responding to the new changes (Table 4.10). The study further concluded that water bird numbers appeared strongly linked to availability of food items which was provided by ideal for growth and increase of their food items. For instance, Long tailed, Great cormorants, Fish eagle, Pied kingfishers, Watch back and Heron preyed on fish increased as fish population increased. This also applied to other aquatic organisms namely: increase of amphibians, invertebrates, algae and other aquatic organisms will favour water birds preying on them. It was also noted that: Hooked shaped beak was used for catching both fish and prey rodents; Stout and spear shaped beak for spearing fish; Long and stout for scooping fish and Flat and hooked for straining algae and small organisms.

The study further concluded that effort and determination put in place by the government and diverse stakeholders in the Lake and its environs had resulted into more farms adopting less wasteful irrigation methods and less chemical application. Similar conclusions were made by David *et al*., (2011). These were attributed to good governance initiatives with a wider network of stakeholders; furthermore, external intervention had been initiated to restore the Lake's ecosystem (David *et al*., 2011). This conclusion was in agreement with Gitahi, (2002) who noted stakeholder's high level of awareness on the adverse effects of these pesticides. Similarly, Getenga *et al*., (2000) agreed that advocacy on appropriate use of pesticides based on recommendation to mitigate their adverse impact on the environment had been ongoing. Moreover, trade unions were putting pressure on the global floriculture industry to develop and conform to codes of conduct for workers' health and safety (FAO, 2010).

## 6.2 Recommendations

The study recommended for continuous study on water physico-chemical parameters in the Lake. This should target potential point sources of contamination around the Lake in order to identify pollution elements in their waste water that cause fluctuation in the water physico-chemical parameters.

The study further recommended for an upgrade in the capacity of laboratories to carry out continuously chemical analysis. This should target pesticide residues in other media including sediments, fish and birds' organs. In the future, pesticide residue analysis on surface water should concentrated more water volume instead of the 100 ml standard used in this study.

The study recommended that further investigation should be done to ascertain the effects of pesticides water birds' tissue especially organs associated with detoxification namely: kidney and liver. Since such organs are associated with higher levels of biomagnifications.

## 6.3 Area for further research

Floricultural sector generates millions of foreign exchange to our country. Successful as it is guarantees our country economic growth since it employs thousands of people. The study recommends that further research on pesticide residue analysis should be carried out on a continuous basis while targeting bottom sediments along the river bed flowing into the Lake. Timing in sample collection will be of essence while targeting period of peak pesticide applications. This will form important source of information for policy makers on the restoration, conservation and management of Lake Naivasha and its environs. Furthermore, this will help guide policies on efficient risk assessment strategies to inform appropriate mitigation measures and safeguard our export markets especially following strict international trade regulation on maximum pesticide residues limits.

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