# Factors affecting foraging and reproductive success of Kittlitz's Plover (*Charadrius pecuarius* TEMMINCK) at two soda lakes in eastern Rift Valley, Kenya

**BY**

**OLIVER NASIRWA**

**BSc, Moi University, Eldoret, Kenya**

**MSc, University of East Anglia, Norwich, United Kingdom**

**A THESIS SUBMITTED TO THE UNIVERSITY OF NAIROBI IN FULFILMENT OF REQUIREMENTS FOR AWARD OF DOCTOR OF PHILOSOPHY IN ZOOLOGY**

**2015**

# CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## DECLARATION

This thesis is my original work and has not been submitted to any other university for any other award.

Oliver Nasirwa ____________________ 14th August 2015

Signature Date

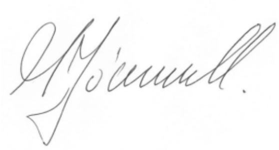
This thesis has been submitted with our approval as supervisors

Prof. Nathan Gichuki ____________________ ____________________

University of Nairobi Signature Date

Dr. John Githaiga ____________________ ____________________

University of Nairobi Signature Date



Dr. Mark O'Connell ____________________ 14th August 2015

External Supervisor Signature Date

## DEDICATION

To my son, Trevor Nasirwa and those working to conserve shorebirds and their habitats.

## ACKNOWLEDGEMENT

Special thanks go to my supervisors Nathan Gichuki, John Githaiga and Mark O'Connell for their direction, diligence, guidance, encouragement, patience and support. I'm grateful for the many discussions and directions. I'm also indebted to Robert Chira for his advice, encouragement and support in many ways.

I thank the National Museums of Kenya for providing a base for my research work, support and assistance in data collection and access to information that helped structure the study. In particular I thank Muchai Muchane, David Gitau, Sylvester Karimi, Patrick Gichuki, Stephen Wamiti and Bakari Ng'ang'a.

I'm also indebted to the Kenya Wildlife Service and the Soysambu Estate for their cooperation and assistance in accessing the study sites as well as provision of information and support during the study.

This study was made possible through an initial grant from the British Ecological Society and support from SIDA through MFS from the Tropical Ecology Department at SLU. Special thanks to Jordi Altimiras and Elisabet Iversen who assisted in obtaining the support from SIDA.

I give gratitude to my family particularly my late wife Pauline Nasirwa (God rest her soul) and my son Trevor Nasirwa for their support and understanding.

## ABSTRACT

Ground nesting shorebirds are perennially at risk from an array of threats arising from activities of humans, other animals and climate induced factors. People and wild animals can destroy nests and kill young birds as well as cause direct and indirect disturbance on shorebirds. Climate variability influences the hydrological cycle thereby causing changes in lake water levels and the extent of the shorelines in aquatic ecosystems. Lakes Nakuru and Elmenteita situated in Kenya's Rift Valley are internationally important for the conservation of shorebirds and are facing the pressures of increase human activity and climate variability. This study investigates how these factors influence the foraging and breeding success of Kittlitz's Plover (*Charadrius pecuarius* TEMMINCK) at these two lakes. Specific objectives were to determine the population size, potential food and foraging behaviour as well as assess the breeding performance of the Kittlitz's Plover.

The study established that Lake Nakuru and Lake Elmenteita support a maximum of 544 and 124 birds respectively giving a total estimate of 668 birds. The two sites combined give a long term mean (±SD) population of 285.3 ± 162.6 birds, which is approximately 0.29% of the world population of the species. An assessment of invertebrates, as potential food for the Kittlitz's Plover using pitfall traps, identified fourteen taxonomic families in six orders of Arthropods. Coleoptera comprising 96% and 89% of all the invertebrates captured at Lakes Elmenteita and Nakuru respectively were the most abundant potential prey. The foraging rates were significantly higher in areas with low human disturbance. The mean (±SD) Foraging Effort (i.e. number of steps made per individual in 30

seconds while foraging) at Lake Nakuru was 34.83 ± 9.74, which was significantly higher (Mann-Whitney U = 1373.5, n = 63, $P$ = 0.003) than that of Lake Elmenteita (30.95 ± 9.36). The mean (±SD) Foraging Efficiency (i.e. number of pecks made per individual in 30 seconds while foraging) was also significantly higher at Lake Elmenteita (9.24 ± 4.11) compared to Lake Nakuru 7.24 ± 4.11 (Mann-Whitney U = 1381.5, n = 63, $P$ = 0.003). The mean (±SD) Food Intake rate (i.e. number of swallows made per individual in 30 seconds while foraging) was also higher in Lake Elmenteita (4.70 ± 2.41) than Lake Nakuru (3.70 ± 2.41) (U = 1506.5, n = 63, $P$ = 0.019). Overall, the birds at Lake Elmenteita experienced higher food availability, spent less energy feeding and achieved higher foraging success rate compared to those resident in Lake Nakuru. Nesting success of Kittlitz's Plover was highest in medium level disturbance areas and lowest in areas of highest human activity. The main causes of nest failure were flooding (52%), vehicle damage (36%) and predation (12%). Using the Mayfield nest loss estimator, Lake Elmenteita had higher nesting success rate (43%) than Lake Nakuru (37%). The combined nest survival rate for the two lakes was 41%, which indicates that the two sites were still good for breeding by Kittlitz's Plover. Results of this study revealed no significant difference between the two lakes in the number of nests built, eggs laid and chicks hatched. Lake Elmenteita contributed significantly more chicks (72.7%, 48/66) compared to Lake Nakuru at 27.3% (18/66). The mean (± SD) number of tourist vehicles (21.7 ± 42.7) and people (6.3 ± 17.0) walking per kilometre of shoreline per day, was higher at Lake Nakuru compared to Lake Elmenteita where no tourist vehicles were recorded. The mean (± SD) number of wild mammals, including predators, in the Kittlitz's Plover habitats at Lake Nakuru was estimated at 23.2 ± 58.0 per kilometre of shoreline per day. The frequency of human, herbivore and predators' foot prints, tyre marks and dung piles revealed higher disturbance levels at Lake Nakuru by large mammals (64.1%), humans (81.7%) and vehicles (92.9%) than at Lake Elmenteita where the frequencies of those threats stood at 35.9%, 18.3% and 7.1% respectively.

The upward trend in visitor numbers, especially at Lake Nakuru and growing settlements around Lake Elmenteita, envisage increased human disturbance along the lake shores. The changes in climatic conditions envisage increased occurrences of flooding and drought. The study recommends instituting mitigation measures such as increased awareness about the breeding birds, zoning of the shoreline for visitors and digging of trenches to curb human disturbance and climate impacts, and conserve the nesting birds.

## STRUCTURE OF THE THESIS

Chapter One introduces the Kittlitz's Plover and how the ecotourism and recreation activities, other wildlife and climate affect its breeding and reproductive success. This chapter deliberates on the situation giving some background information, literature review, rationale and hypothesis. Chapter Two presents the study areas, materials and methods. Chapter Three covers population size, distribution and movement of Kittlitz's Plover. Chapter Four assesse the occurrence, diversity and abundance of invertebrates as potential food of the study species; Chapter Five presents studies on the factors that influence the foraging rates of the species in the different sites; Chapter Six covers the nesting success; Chapter Seven discusses aspects of the breeding ecology and Chapter Eight covers impacts of human and animal disturbance, and climate effects on the breeding success of Kittlitz's Plover. Chapter Nine, which is the final chapter, covers general discussion, conclusions and recommendations.

# CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

## 1.1 General introduction

Wetlands are some of the most functionally important and productive ecosystems on earth (Mitsch and Gosselink, 1993). Despite this fact, wetlands continue to face an ever-increasing range of threats, and large areas and important sites are being lost to agriculture and infrastructure developments (Dixon and Wood, 2003). The quality of wetland habitats is further degraded through pollution, siltation and disturbances from a range of human socio-economic activities (Acreman and Hollis, 1996). As a result of anthropogenic activities, over 50% of wetlands in the world have been lost in the past century (Fraser and Keddy, 2005). Research has shown that these losses and degradation of wetlands has negatively affected the distribution, population size and diversity of a broad range of species that depend on wetland habitats (Ma *et al.,* 2010). Given these issues with waterbirds, it is essential to provide a description and understanding of the spatial and behavioural ecology of these important environmental indicators (Gregory *et al.,* 2008).

## 1.2 Waterbirds and habitat quality

For the conservation of waterbirds and their habitats, a key issue would be on how to use research to prioritise actions such as identification and designation of key sites based on habitat quality. In some cases, sites with the most birds are often fundamentally higher in quality and should be prioritized for conservation. However, there are also numerous ecological factors that might lead birds to select sub-optimal sites and even positively avoid some apparently suitable wetland habitats (Battin, 2004; Schlaepfer *et al.,* 2002; Kristan, 2003; Robertson and Hutto, 2006; Kokko and Sutherland, 2001; Gilroy and Sutherland, 2007; Shochat *et al.,* 2005; Patten and Kelly, 2010). Habitat quality is therefore best measured from an individual bird's perspective and can be defined as the per capita rate of population increase expected from a given habitat. Habitat selection is therefore the behavioural process used by individuals when choosing resources and habitats (Johnson, 2007; Morris, 2003). Using this approach human disturbance of birds is considered to be any human activity that influences a bird's behaviour (proximal response) or survival (ultimate response) (Liley, 1999). Breeding success can then be measured as a proxy indicator of habitat quality.

### 1.3 Human disturbance

The effects of a disturbance event on an animal's behaviour are not necessarily the same as impacts of that disturbance event. The effect of a one-off disturbance event may make an animal to temporarily leave a feeding area (Beale, 2007). Leaving a foraging area might be assumed to be a negative impact, but is likely to be largely negligible compared to an animal that returns or stays and is thus subjected to repeated stimuli (Gill *et al.,* 2001). The animal that stays may show no behavioural effects, but may suffer physiological stresses (Beale, 2007). Hence, in the interest of conservation and animal welfare, we should be much more interested on impacts rather than simple effects (Gill *et al.,* 1996; Nisbet 2000). This crucial difference is often ignored when researchers equate effect with impact: certainly human disturbance affects animal behaviour, but this does not necessarily mean human disturbance has a (negative) impact on animal conservation or welfare (Beale, 2007).

### 1.4 Ecotourism trend

Ecotourism and recreation activities are increasing worldwide (Junk, 2002) and as a result, human contact with birds and other wildlife is becoming more frequent (Ikuta and Blumstein, 2003). Improved infrastructure continues to provide holiday makers with increased access to scenic areas of wetland habitats especially to beaches and shoreline areas (Belsoy *et al.,* 2012; Sunlu, 2003; Davenport and Davenport, 2006; Jędrzejczak, 2004). The effects of human disturbance are often more severe in shoreline habitats, because of their linear nature (Burger, 1991; Burger and Gochfeld, 1991). Shorebirds are particularly vulnerable to disturbance during the breeding season, when they are restricted to their breeding territories and the incubation of eggs and rearing of young adds extra exposure and constraints on the behaviour of parental birds (Thomson *et al.,* 1998). An understanding of the influence of human disturbance on habitat quality for waterbirds is particularly important for planning conservation measures, such as controlling visitor numbers or zoning public access to breeding areas (Gill, 2007; Isaksson, 2009; Beale and Monaghan, 2004; Sutherland, 2007; Nisbet, 2000; Ikuta and Blumstein, 2003).

## 1.5 Ecology of the Kittlitz's Plover

The Kittlitz's Plover is a small buff breasted bird measuring about 15 cm in length. **Adult** birds have a distinctively white super-ciliary stripe and black eye-lines which meet around the hind-neck. The forehead is white bordered posteriorly by black frontal bars. The toes and feet are dark-greenish-grey. In flight, the bird shows dark leading wing edges, white wing-stripes, white tail sides, and toes project beyond tip of tail (Zimmerman *et al.,* 1996) (Figure 1.1).

**Figure 1.1 Kittlitz's Plover (*Charadruis pecuarius* TEMMINCK) adult and dawny young.** An illustration by Urban *et al* (1986).

**Dawny young** have grey to white upperparts and mottled black with dark centre line on the back (Urban *et al.*, 1986). The young are precocial and nidifugous, cared for by both parents and self-feeding (Conway and Bell, 1968).

**Juveniles** have continuous buff on forehead with pale superciliary stripes and band around the nape, lacking the black frontal bars and the bold face pattern. Their breasts are pale buff, with distinct brownish patches at the sides (Zimmerman *et al.,* 1996).

Kittlitz's Plover is considered to form superspecies with the Black-banded Plover, *C. thoracicus* and St. Helena Plover, *C. sanctaehelenae*. It is conspecific with St. Helena Plover, *C. sanctaehelenae* (Del Hoyo *et al.,* 1992). The Black-banded and St. Helena Plovers are listed as globally Vulnerable and Endangered respectively on the IUCN Red List (Del Hoyo *et al.,* 1992; Collar *et al.,* 1994).

Kittlitz's Plover is common and widespread over suitable habitats in Africa and Madagascar (Del Hoyo *et al.,* 1992; Collar *et al.,* 1994). It prefers dry ground with very short grass or dried mud, usually but not always near water. It is known to inhabit edges of dams, lakes, rivers, tidal mudflats, dry salt flats and floodplains, but avoids sandy or rocky shores. Its status ranges from abundant to rare and resident to partly migratory in inland as well as coastal habitats of Africa. The species makes seasonal movements that are not well understood, but seem to be regulated by seasonal rainfall with the birds leaving during rains and high floods (Urban *et al.,* 1986). Due to the widespread range of the Kittlitz's Plover in Africa, it is a useful model species for studying spatial scale changes associated with the environmental conditions of the habitats it prefers.

Kittlitz's Plovers in the Eastern, Central and Southern Africa are considered as one population in the race *Charadrius pecuarius pecuarius*, which is estimated at more than 100,000 individuals (Delaney *et al.,* 2009). In Kenya the peak laying dates documented coincide with the rainy seasons of April to June and November, but egg-laying could happen anytime all year round (Urban *et al.,* 1986; Del Hoyo *et al.,* 1992). Hatching success is known to range from 77% in Zimbabwe (Tree, 1974) to 52% in Southern Africa (Blaker, 1966) and 19% at Lake Nakuru (Kutilek, 1974). Mortality is mainly due to flooding of nests, vehicles crushing nests and young, and predation (Urban *et al.,* 1986). These variations in hatching success from country to country could be due to the differences in the flooding regimes and access of vehicles and human traffic at their breeding sites.

The apparent changes and effects on the distribution of the species in its different sub-habitats and sections around Lake Nakuru in the 1990's have been attributed to lake level fluctuations (Owino, 2002). A number of aspects of the breeding behaviour of Kittlitz's Plover have been documented, but the effects of the factors affecting the species' reproductive success with population level consequences have not been studied.

The species is relatively common and therefore allows flexibility in researching the environmental variables that could contribute to the understanding of the effects of human disturbance, predation and the impact of lake level changes to waterbird populations in wetlands in the Africa. Advances in ecology make it possible to quantify the effect of human disturbance on animal populations (Gill *et al.,*1996; Gill, 2007), including those documented on foraging behaviour (van de Kam *et al.,* 2004), and mating patterns (Székely, 1992; Székely and Williams, 1994) as well as movements of shorebirds (Ward 2000; Robinson *et al.,* 2005; Nichols and Kaiser, 1999).

### 1.6 Rationale of the study

The study is a response to the increased socio-economic activities in wetland habitats impacting on Lakes Nakuru and Elmenteita. These two lakes are designated as Wetlands of International Importance under the Ramsar Convention and World Heritage Sites under the United Nations Educational, Scientific and Cultural Organization (UNESCO). Thus, the two lakes are of high conservation interest to the Government of Kenya. These lakes support a breeding population of Kittlitz's Plover and thousands of Palearctic migrant waterbirds.

This study sought to measure the impact of human activities on the shorelines of Lakes Nakuru and Elmenteita on foraging and reproductive success of the Kittlitz's Plover. The outputs of this study not only support and underpin efforts to conserve waterbirds at the shorelines of these two sites, but also contribute to benefit the wider and more general development and biodiversity conversation efforts.

## 1.7 Aim of the study

The aim of this study was to improve the conservation and management of shorebirds at Lakes Nakuru and Elmenteita. These two lakes are of international importance under the Ramsar Convention, Important Bird Areas under BirdLife International and World Heritage Sites under UNESCO. This is done through assessing ecological requirements for the Kittlitz's Plover, including potential food sources, breeding requirements, threats to the species, and ascribing appropriate conservation measures.

## 1.8 Research questions

1. How does human disturbance, water level and climate impact on population size, distribution and movement of Kittlitz's Plover at Lakes Nakuru and Elmenteita?
2. How does human disturbance, water level and climate impact on the foraging habitat and behaviour of Kittlitz's Plover at Lakes Nakuru and Elmenteita?

3. How does human disturbance, water level and climate impact on the breeding success of Kittlitz's Plover?
4. What are the management implications of human disturbance, water level and climate on the conservation of Kittlitz's Plovers at Lakes Elmenteita and Nakuru?

## 1.9 Research objectives

The study has the following four objectives:-

1. To determine the impact of human disturbance, water level changes and climate on movement, population size and distribution of Kittlitz's Plover at Lakes Nakuru and Elmenteita.
2. To determine the impact of human disturbance, water level changes and climate on foraging of the Kittlitz's Plover at Lakes Nakuru and Elmenteita.
3. To determine the impact of human disturbance, water level changes and climate on the breeding success of Kittlitz's Plover at Lakes Nakuru and Elmenteita.
4. To determine management implications arising from human disturbance, water level changes and climate for Kittlitz's Plover at Lakes Nakuru and Elmenteita.

## 1.10 Research hypothesis

This study was based on the following two research hypothesis:-

1. The abundance, distribution and movement of Kittlitz's Plover are a response to human disturbance, water level changes and climate change at Lakes Nakuru and Elmenteita.
2. The foraging and breeding success of Kittlitz's Plover at Lakes Elmenteita and Nakuru are affected by human disturbance, water level changes and climate change.

# CHAPTER 2: STUDY AREA, MATERIALS AND METHODS

## 2.1. Study area: general attributes

The study area covers Lakes Nakuru and Elmenteita, which are approximately 15 km apart. Both lakes have bare ground areas along their shorelines interspaced as well as fringed by salinity tolerant grasses and sedges. The flooding and receding regimes of the lakes maintain these bare shoreline areas known to be utilised by the Kittlitz's Plover and other shorebird species (Nasirwa and Bennun, 2000; Owino *et al.,* 2002; Bennun and Nasirwa, 2000; Owino *et al.,* 2001). The bare areas around the lakes are interspaced with short grasses and sedges, which attract herbivores that graze or use these areas as movement routes.

### 2.1.1 Lake Nakuru

#### 2.1.1.1 Location, altitude and size

Lake Nakuru is located between latitudes $0^{o}10'$- $0^{o}24'$S, and longitudes $36^{o}04'$-$36^{o}07'$E, at an altitude of 1758 m above sea level (ASL) and covers an area of approximately 45 $km^2$ of Lake Nakuru National Park. The nearest major town is Nakuru, approximately 1.5 km to its north.

#### 2.1.1.2 Climatic conditions

The rainfall at Lake Nakuru is bimodal with two wet and dry seasons. The two wet seasons – long and short rains fall between April and August, and October to November, respectively. The mean annual rainfall over the lake is 876 mm, but with substantial annual variations. Highest rainfall is recorded in the months of April, May and August. The driest months are January and February. On average: the warmest month is March, coldest is August, wettest is April and driest is January. The temperatures range from 8°C to 28°C with an average Relative humidity of 60%.

#### 2.1.1.3 Drainage, water level and hydrology

The lake catchment is bound by the Menengai Crater to the north, the Bahati Hills to the north-east, Lion Hill ranges to the east, Eburu Crater to the south and Mau escarpment to the west. The lake is fed by three perennial rivers namely, Makalia, Njoro and Nderit, and also receives inflows from the treated sewage works and several springs along the shore (Figure 2.1). The lake has no outlet. The water level and extent to the adjacent areas fluctuates seasonally and over cycles of few years, though in some years the lake has been known to dry completely (Bennun and Njoroge, 1999). The mean depth is 1.5 m, but can fluctuate from 0 m to maximum of 4 m between or within the same season, depending on prevailing climatic conditions (Varesch, 1978; Githaiga, 2003).

#### 2.1.1.4 Water quality and sediments characteristics

The lake has a mean salinity of 45%, a pH of 10.5 and an alkalinity of 30 meq/l (Vareschi and Vareschi, 1984). The lake shore constitute of alkaline mud derived mainly from alluvial deposits that have developed through weathering under lacustrine conditions (Vareschi, 1978; Githaiga, 2003).

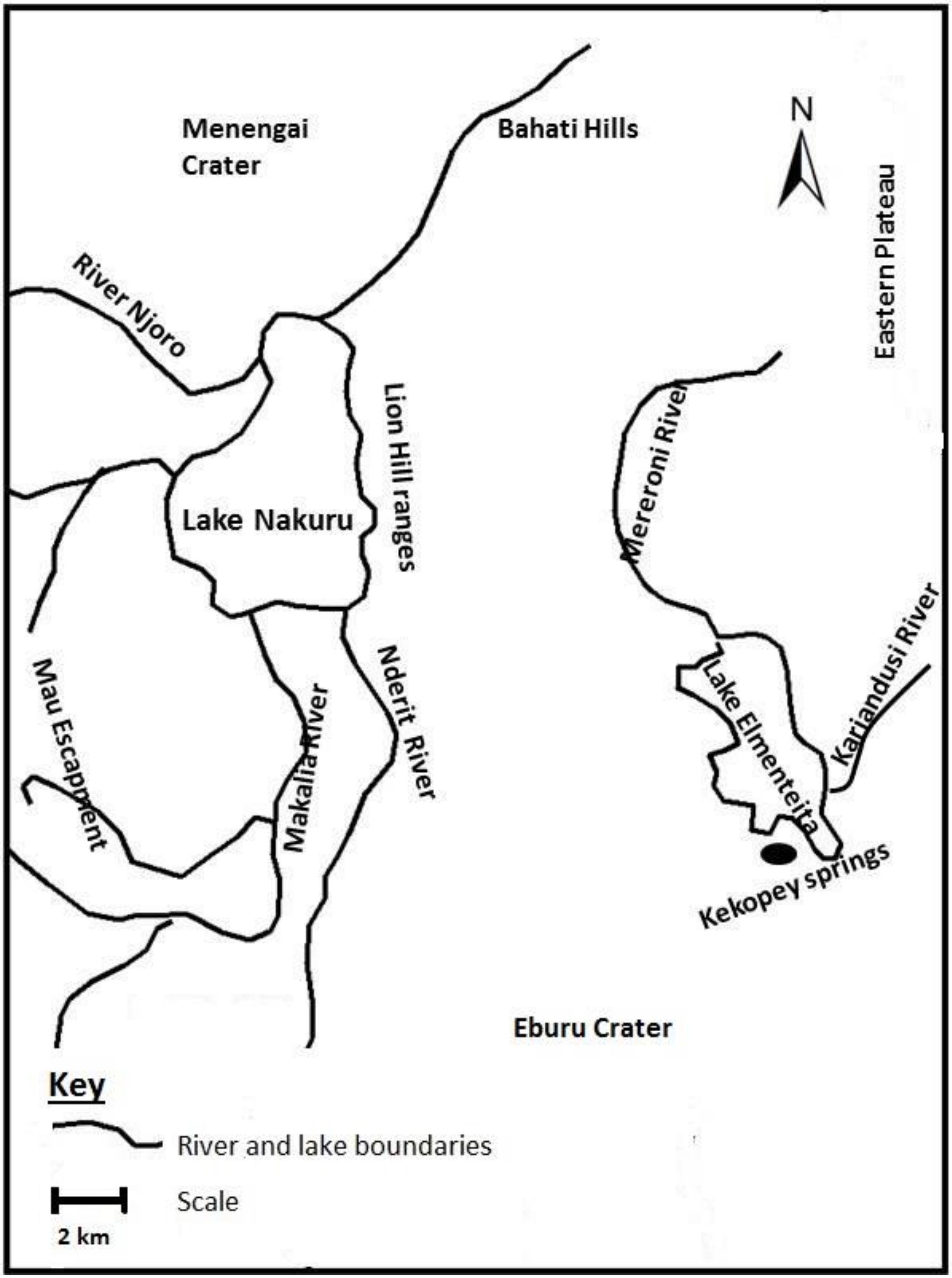



**Figure 2.1 Map of Lakes Nakuru and Lake Elmenteita area**

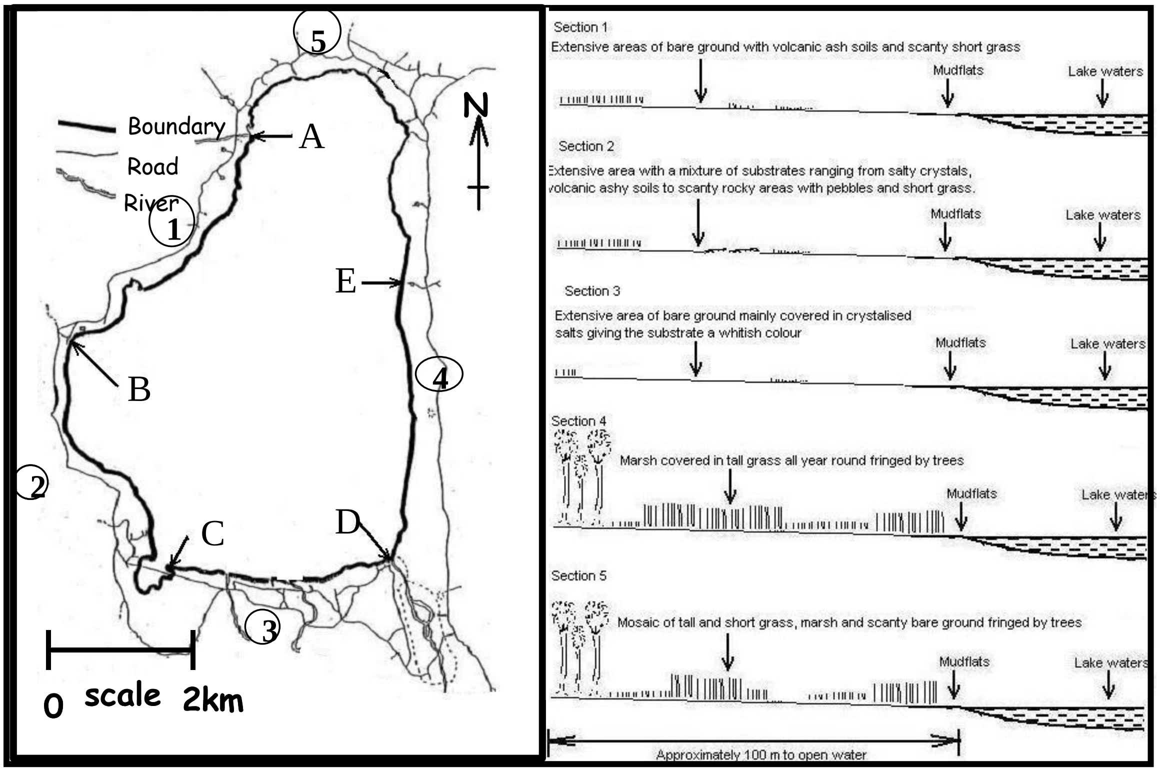



**Figure 2.2 Lake Nakuru study site and sections.**

The lake is marked from point A to E and numbered from section 1 to 5. Cross-sections of the shoreline characteristics of the different sections of the lake are illustrated in the box on the right.

### 2.1.1.5 Flora and fauna

Lake Nakuru is rich in plant diversity with 556 plant species from 305 genera and 85 families recorded (Republic of Kenya, 2010). The vegetation around the lake include *Cyperus laevigatus* mainly around the margins at the fringes of the mudflats, with *Sporobolus spicatus* swards behind it. *Typha domingensis* is found at the mouths of the inflow streams. The surrounding terrestrial habitats bordering the lake are savannah grassland that extend into Acacia woodland, forest or grasslands with occasional Acacia trees. There are hills close to the lake in the east and west.

The documented macroinvertebrates include chironomids, culicinae larvae and annelids (Gichuki *et al.,* 1997). About 450 species of birds have been recorded at Lake Nakuru National Park. The waterbird communities include flamingos, grebes, pelicans, storks, ducks, spoonbills, sandpipers, plovers, snipes among other species. The Greater (*Phoenicopterus ruber*) and Lesser (*Phoeniconias minor*) Flamingos dominate in the waterbird populations. Over 1.5 million Lesser Flamingos having been recorded in this lake (Bennun and Njoroge, 1999). Other wildlife include a wide range of mammals, such as the Black (*Diceros bicornis*) and White (*Ceratotherium simum*) Rhinoceros, Rothschild's Giraffe (*Giraffa Camelopardalis rothschildi*), Burchell's Zebra (*Equus burchellii*), Cape Buffalo (*Syncerus caffer*), Common Warthog (*Phacochoerus africanus*) and Deffassa Waterbuck (*Kobus ellipsiprymnus*) and Impala (*Aepyceros melampus*), Lion (Panthera Leo), Leopard (*Panthera Pardus*), Spotted Hyena (*Crocuta crocuta*) and Cheetah (*Acinonynyx jubatus*) among others.

#### 2.1.1.6 Conservation and land use

Lake Nakuru was gazetted as a bird sanctuary in 1960 and a National Park in 1974. It became Kenya's first Ramsar Site, designated under the Ramsar Convention (1971), as a wetland of international importance in 1990 (Fanshawe and Bennun, 1991). It attracts about 300,000 tourists a year. Most tourists are attracted by its diverse wildlife and especially the huge spectacular flocks of the two species of flamingos (*Phoenicopterus ruber* and *Phoeniconias minor*) that are easily viewed from the shores of the lake. The lake faces huge threats mainly from pollution through industrial waste, domestic sewage and agricultural waste from surrounding farmland and the adjacent Nakuru Town, and heavy tourism (Bennun and Njoroge, 1999).

#### 2.1.1.7 Nature and sources of disturbance

The western and southern sections of the lake are openly accessible to visitors where they walk and easily drive along the length of the shoreline. In these areas visitors disembark from their vehicles and may walk around. The northern and eastern shorelines are closed-off from continuous shoreline access. Visitors to these areas can only access few points along the shore. These areas are colonised by sedges and grasses, and most are marshy. The role and impact of disturbance caused by heavy tourism on the habitats and wildlife around the lake has not been documented.

### 2.1.2 Lake Elmenteita

#### 2.1.2.1 Location, altitude and size

Lake Elmenteita is located at the intersection of latitudes $0^{o}27'S$ and longitude $36^{o}15'E$ and covers an area of approximately 20 $km^2$. It is situated at an altitude of 1776 m ASL and about 25 km from Nakuru Town (Figure 2.3).

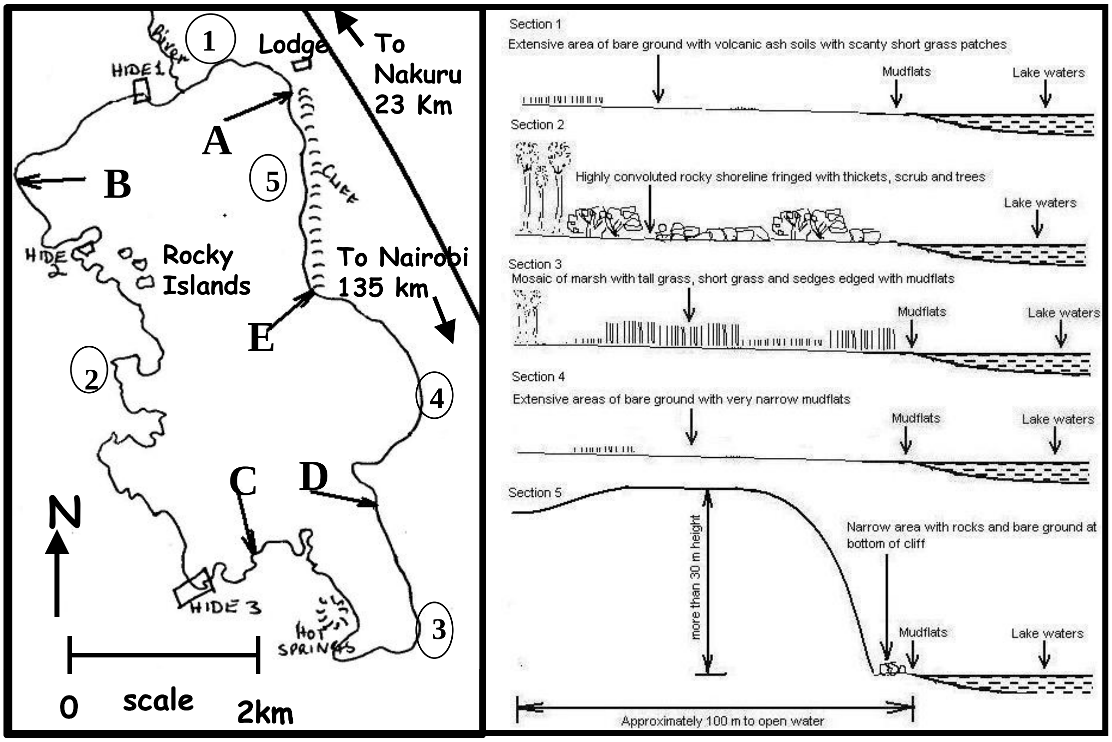



**Figure 2.3 Lake Elmenteita study site and sections.**

The lake is marked from point A to E and numbered from section 1 to 5. Cross-section of the shoreline characteristics in the different sections are illustrated in the box on the right. The lake is situated on the eastern side of the Rift Valley and is oriented North-South. Its southern end is set at the foot of a lava field which rises to 2128 m ASL, while land at the northern end rises to 1950 m ASL.

### 2.1.2.2 Climatic conditions

The rainfall at the Lake is bimodal with two wet and dry seasons. However, the rainfall patterns are erratic at less than 600mm on average per year. The temperatures range from 8°C to 28°C with an average Relative humidity of 60%. The conditions around Lake Elmenteita are generally warmer and drier compared to Lake Nakuru.

#### 2.1.2.3 Drainage, water level and hydrology

This lake is shallow and saline with a mean depth of 1.2 m that fluctuates seasonally and annually with a maximum depth of 1.9 m. It is fed by the Kekopey hotsprings at the southern end, and two small streams, the Mereroni and Kariandusi, flowing from the eastern plateau. There are also perennial warm springs on the south-western side of the Lake. The lake has no outlet.

#### 2.1.2.4 Water quality and sediment characteristics

The lake is saline (c. 40%) with a mean pH of 9.4 and conductivity range from 12 000 - 40 000 uS/cm. Secchi depths vary between 10 and 20 cm (Bennun and Njoroge, 1999; Hughes *et al.,* 1992). The surrounding landscape is characterized by dramatic rocky faults, volcanic rocky outcrops and cones. The northern and south-eastern lakeshores are open and flat, with a cliff on the north eastern side and broken and rocky western shores. The characteristics of soils around the shore are volcanic, alluvial deposits and sandy alkaline mud.

#### 2.1.2.5 Flora and fauna

The natural vegetation is mainly *Acacia sp.* and *Tarchonanthus camphoratus* bushland interspersed with *Themeda triandra* grasslands. Dry bush land cover parts of the eastern, southern and western parts of the lake where dominant tree species include *Acacia xanthophloea* and *Euphorbia candelabrum*. Bush species include *Rhus natalensis*, *Sesbania sesban*, *Lantana trifolia* and *Vernonia spp*.

The Ututu scrubland located to the south of the lake is dominated by *Olea sp*. and *Tarchonanthus camphoratus*. Grasslands close to the shoreline are mainly dominated by *Sporobolus spicatus* and *Chloris gayana*. The terrestrial grasslands are dominated by *Themeda triandra*, *Sporobolus fibriatus*, *Eragrostis spp*., *Pennisetum catabasis* and *Cynodon dactylon*. The marshes on the southern parts of the lake are dominated by *Cyperus laevigatus* and *Typha spp*.

About 400 species of birds have been recorded at Lake Elmenteita and its environs (Bennun and Njoroge, 1999). The waterbird communities include flamingos, grebes, pelicans, storks, ducks, spoonbills, sandpipers, plovers, snipes among other species. The Greater (*Phoenicopterus ruber*) and Lesser (*Phoeniconias minor*) Flamingos dominate the numbers of waterbirds populations. Up to 8,000 pairs of Great White Pelicans (*Pelecanus onocrotalus*) have bred at this lake when water levels are high and rocky outcrops in the eastern sector are flooded to form islets.

Other wildlife include mammals, including such as the introduced Rothschild’s Giraffe (*Giraffa Camelopardalis rothschildi*), Burchell’s Zebra (*Equus burchellii*), Cape Buffalo (*Syncerus caffer*), Common Warthog (*Phacochoerus africanus*) and Impala (*Aepyceros melampus*).

#### 2.1.2.6 Conservation and land use

Lake Elmenteita has a lesser diversity of large game and receives fewer tourists. It however has some human settlement in proximity of its shores, especially to its south. People from these settlements graze their cattle around the southern shore areas of the lake. Unlike Lake Nakuru, Lake Elmenteita is not threatened by urban pollution and receives low number of tourists. However catchment degradation is on the increase. The northern and western shorelines are privately owned as part of the Soysambu Wildlife Sanctuary, while the east and south are accessible to the surrounding communities. The lake was designated as a Ramsar Site in September 2005.

## 2.2 Materials and methods

### 2.2.1 Assessing the population size and distribution

Structured direct counts of Kittlitz's Plover were conducted by walking along the entire shoreline of the two study sites once every month from March 2005 to August 2006. A line transect was used to sample and count individuals of the species along the shore. All individuals detected were counted and recorded. The number of adults and juveniles (flightless birds) were also noted and the data were captured for different sectors of each lake.

Simultaneously, behavioural data on inter and intra specific interactions, foraging, courtship, and breeding (i.e. presence of nests, eggs, pullus, flightless young, incubating adult) were also noted. GPS data of all the sightings and encounters with the birds were recorded. The lengths of the different sections of the two lakes' shorelines were measured and the numbers of the birds, nests, eggs and chicks were expressed as number of individuals per km of shoreline length in the analysis.

### 2.2.2 Bird trapping

The counts described above provided baseline information that was used to identify suitable areas to set-up mist-nets for trapping the plovers. The birds were trapped to mark as well as collect and record standard biometric information for each individual caught. This information is important in assessing demographic characteristics of individuals in a locality. Mist-nets of 60 meters in length were set up as described by McClure (1984) and Svensson (1992) in places within the sites where the study species had been recorded the previous day to maximise the catch (Figure 2.4).

**Figure 2.4 Mistnets set-up to capture Kittlitz's Plovers at Lake Nakuru.** (Photo taken in March 2005).

The nets were opened at 06h00 and closed at 10h00. A ringing station was set-up about 100 meters from the mist-nets, at a location that was sufficient to avoid scaring off the birds from coming to the mist-nets. Information about the site was recoded including: the study section, the date, time started, weather variables (i.e. % cloud cover, wind force, sunny conditions and temperature) and GPS readings. Routinely the mist-nets were checked every 30 minutes. The birds caught were first fitted with a metal ring, followed by a unique combination of three Davic (plastic coloured) rings (Appendix 1 and Appendix 2). One colour ring on tarsus in the same leg as the metal ring and the other two colour rings on the other leg, one on the tibia and the other on the tarsus as described by Ward (2000), Svensson (1992) and Székely *et al* (2008) (Figure 2.5).

**Figure 2.5 Kittlitz's Plover chick showing metal and Davic colour rings put on its right leg at Lake Nakuru.** (Photo taken in March 2005).

### 2.2.3 Biometric measurements

Biometric measurements were taken for each individual bird caught. These biometrics include: **Age:** classify age as young, juvenile, immature or adult by assessing feathers, plumage and body part conditions; **Wing-length:** using maximum flattened chord technique (Svensson, 1992), measured to the nearest mm with butt-ended ruler; **Bill length:** measured along the culmen from the base of feathering to the bill tip, using dial-reading callipers to the nearest 0.1 mm; **Bill depth:** Measured at the base of the nare, using a dial reading callipers (to the nearest 0.1 mm); **Tarsus length:** Using 'leg bent' method of (Svensson, 1992), from notch on the back of intertarsal joint to bend of the foot, using dial reading callipers to nearest 0.1 mm; **Moult scores:** on primary, secondary and body feathers; **Weight:** was measured using a weighing bag and spring balance to neared 0.1 g. After weighing, the bird was checked for fitness and then released from near the place it was captured.

### 2.2.4 Measuring foraging rates

Foraging rates were measured as described by (Liley, 1999). Visits were made to the study sites that had foraging Kittliz's Plover and foraging data collected. Once at the study site, the following information was first recorded: the study section, the date, time for starting the observations, weather variables (i.e. % cloud cover, wind force, sunny condition and temperature) and the number of Kittlitz's Plover at the section.

With the aid of a telescope set at a vantage point, an individual foraging Kittlitz's Plover was randomly selected and observed for 30-second intervals. Within the 30 seconds: the number of steps (as measure of foraging effort), the number of pecks (as a measure of foraging efficiency) and the number of prey items consumed (as a measure of prey intake) were recorded. After 30 seconds a new individual was selected and repeat data were recorded. Thereafter, the exercise was repeated in the other sections of the study sites.

### 2.2.5 Mapping nests and hatching success

Systematic searches and scans of the study area were made at intervals of 200 m along the lakeshore to collect evidence of breeding activities (nests, pullus, juveniles, incubating birds) using a telescope. Nests were located by watching particular types of behaviour known to be characteristic of incubating birds (e.g. birds stood-up over the nest and kicked sand on its eggs before departing the nest). This behaviour has been described previously in the field and in captivity (Conway and Bell, 1968; Hall, 1958; Hall, 1959; Kutilek, 1974). More clues were used to locate the parents with young.

Once a nest was located, the following were recorded: (1) GPS position of nest; (2) description of general area where nests were situated (i.e. any nearby vegetation, micro-topography, nature of soil and other materials beyond one meter); (3) with nest as the centre, a 1x1 meter quadrat was placed and the percentage vegetation cover, soil characteristics, pebbles, stones and any other materials within the quadrat were measured; (4) lining material used in the nest; (5) when the nest is approached, the distance at which the bird left the nest; (6) behaviour displayed before, during and after the bird left the nest; (7) number of eggs; (8) number of chicks; (9) weight of eggs; (10) weight of chicks; (11) length of eggs; (12) width of eggs; (13) capture and ringed chicks that were estimated to be more than one week old; and (14) moved about 200 m distance away from nest and recorded the time taken for the bird to resume incubation.

Where active nests (i.e. with eggs) or where flightless young were found, additional data were collected. Funnel traps were used to capture adults by placing the traps over the nest or over the flightless young (McCulloch, 1991; Székely *et al.,* 2008; Liley and Sutherland, 2007).

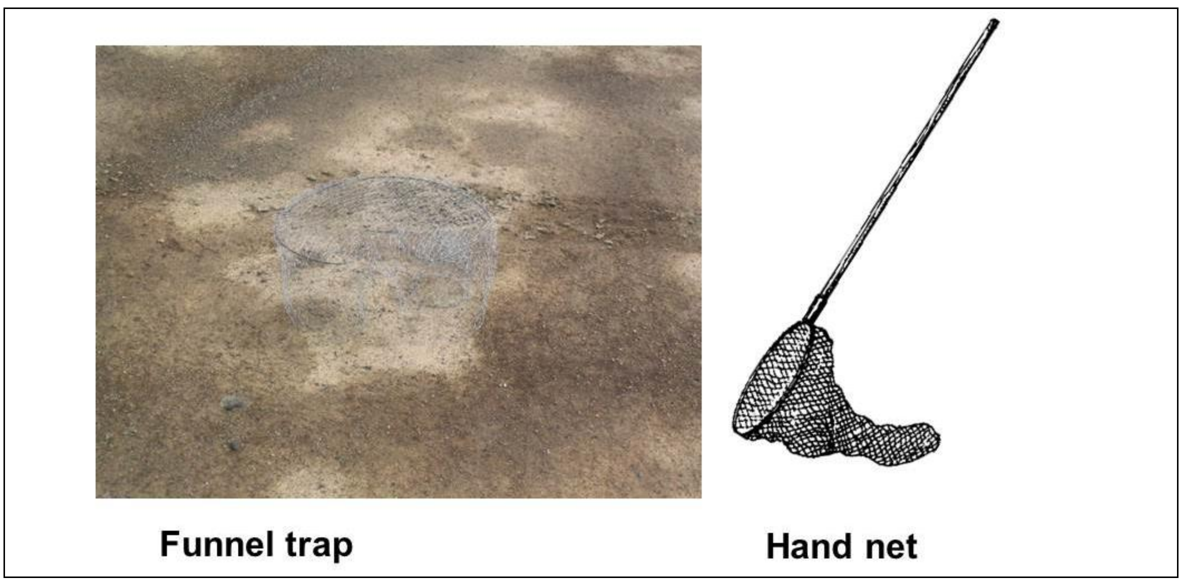



**Figure 2.6. A funnel trap and hand net used for capturing Kittlitz's Plovers.**

These lured the adults into the trap and were captured. Hand-nets were used to pursue flightless young and capture them (Figure 2.6). All captured individuals were ringed and biometric data recorded. The initial plan was to revisit nests and recapture flightless young after four-day intervals. The revisits to nest were abandoned due to the low number of nests and pullii found. This also reduced observer disturbance resulting from our efforts to locate the nests and flightless young. In this light, efforts were instead directed towards locating new nests and chicks.

### 2.2.6 Measuring nesting success

One hundred and forty-five dummy nests with eggs made of plasticine as described by (Møller, 1987) were used in this experiment. The dummy eggs were coated with a creamy white paint and scented with Kittlitz's Plover faeces. They were then placed systematically around the two study sites. The eggs were made to resemble the Kittlitz's Plover eggs in size, shape and weight (Hall, 1958). The sizes ranged between a length of 29.6 mm to 34.7 mm and width of 19.0 mm to 23.6 mm, and weighed between 10 g to 11 g.

The dummy eggs and nests were distributed systematically along the shoreline in the different sections of the lakes. Each dummy nest was placed about 50 m from each other and approximately 50 m from the shoreline in sets of 20 per section for the three sections of Lake Nakuru. At Lake Elmenteita in the northern section, the nests were placed in two parallel rows along the shoreline. One row was placed at approximately 50 m and the other at 100 m from the shoreline. Each row had 36 nests spaced at 50m. In the southern section 32 nests were placed at 50m from the shoreline and 50 m from each other running along the shoreline.

The nests were formed by hand into a shallow scrap with a clutch of two artificial eggs each. The eggs were partially covered with soil (resembling natural behaviour of Kittlitz's Plover) (Hall, 1958). A total of 61 and 84 dummy nests were placed along the shores of Lakes Nakuru and Elmenteita respectively within areas of known occupancy by Kittlitz's Plover's individuals.

The dummy nests and eggs were then monitored once every four days for a period of 28 days from 23$^{rd}$ August 2005. The 28 days covers the maximum incubation period for the species (Hall, 1958). During this period, data on the number of dummy eggs and the nests displaced or damaged were recorded. The eggs and areas around the nest were also examined closely to identify any marks left by predators. Rainfall data for the study area were also collated during the entire study period.

### 2.2.7 Measuring human and animal disturbance

Sampling using 1x1 meter square quadrat to collect data on substrate condition in the different sections of the study area was carried out. At Lake Nakuru the study sites were divided into three sections (NAK1, NAK2 and NAK3) and Lake

Elmenteita two sections (ELM1 and ELM2) (Figure 2.7). Sections C to D and D to E at Lake Elmenteita were combined due to the constant fluctuation of the lake shoreline in the south.

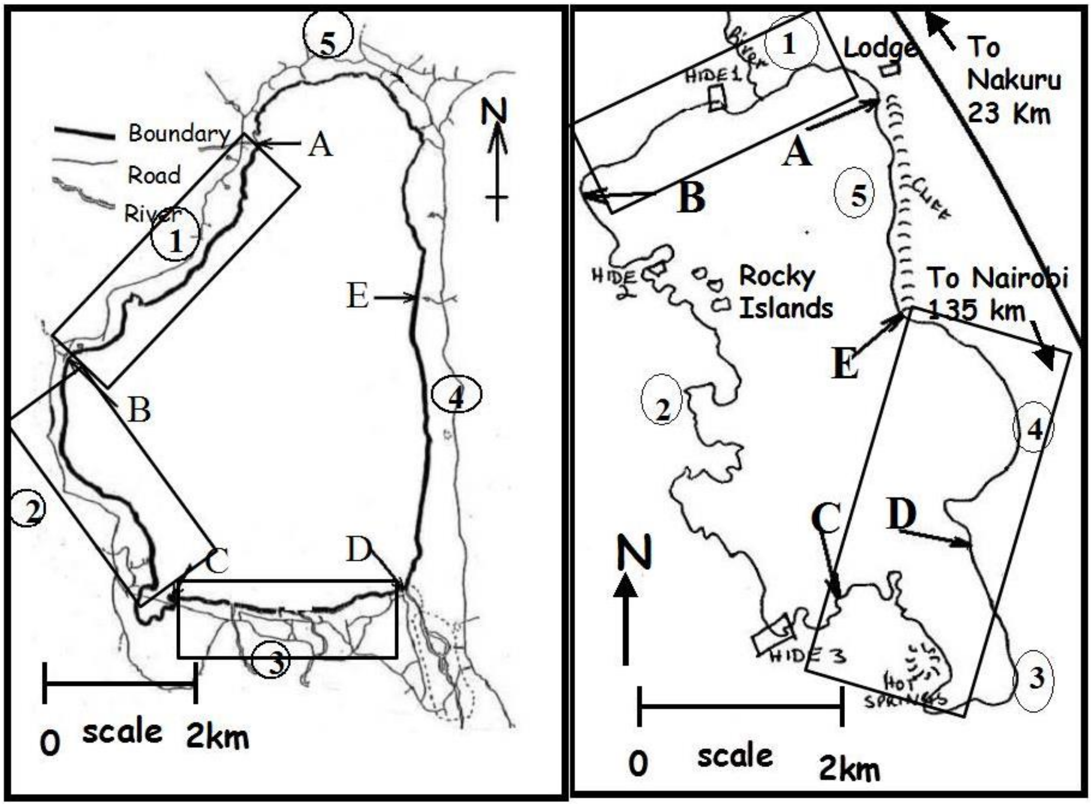



**Figure 2.7 Sampling sections of Lakes Nakuru (left) and Elmenteita (right).**

Points A, B, C, D and E mark the beginning and ending of each section numbered 1, 2, 3, 4 and 5).

Random X and Y coordinates were generated for blocks of 20 quadrats (Appendix 3). In each quadrat the following data were collected: (1) soil type, colour and texture; and (2) scores to denote presence of litter (solid waste), animal (herbivore) footprints, human footprints, predator (mammalian or bird) footprint, vehicle tyre marks and herbivore dung. The sampling in the two study areas was completed between 13th August and 20th August 2005.

### 2.2.8 Measuring the abundance of invertebrates as potential food

During September 2006, sets of six pit-fall traps were set-up systematically (Figures 2.8) within the study sites. The traps were made of plastic cylindrical cups measuring 70 mm in diameter and 100 mm in height. The set of six cups were dug into the ground, and placed two meters apart. The brim of the cups was set at same level with the ground level. The cups were filled with water and a drop of detergent, added so as to break the surface tension of the water. The traps were monitored and invertebrates harvested to gather samples for 12 hours day (06h00 to 18h00), 12 hours night (18h00 to 06h00) and 24 hours again (06h00 to the next day at 06h00).

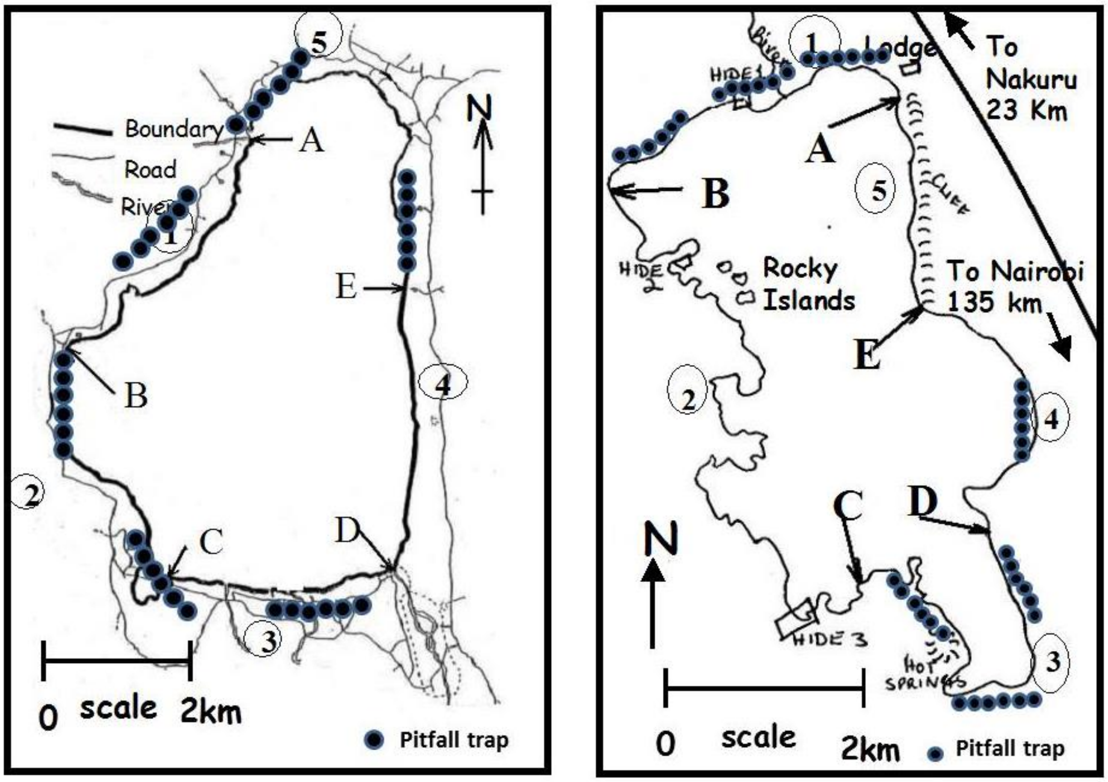



**Figure 2.8 Location of pitfall traps (solid dots) for invertebrate sampling around Lakes Elmenteita (right) and Nakuru (left).**

# CHAPTER 3: POPULATION SIZE, DISTRIBUTION AND MOVEMENT

## 3.1 Abstract

The Kittlitz's Plover is among the few wader species that breed on bare ground along shores of Lakes Elmenteita and Nakuru in Kenya. A sixteen-year (1991 to 2006) count dataset of numbers of Kittlitz's Plover covering the months of January and July for Lakes Nakuru and January for Lake Elmenteita were analysed. These data were supplemented by an 18-month survey of the species at the two sites. The species was found to be more abundant at Lake Nakuru compared to Lake Elmenteita prior to 2002. This situation changed from 2003 to 2006 where the birds became more abundant at Lake Elmenteita. This shift was attributed to changes in the rainfall patterns and in the extent of the open shores. The species' abundance at each lake was independent of each lake's condition and its preference was for open shoreline areas. The maximum number of birds the two sites ever supported (pooled) was 668 birds in January 2000, when Lake Nakuru supported 544 and Lake Elmenteita 124 birds. The two sites combined give a long term mean (±SD) count of 285.3 ± 162.6 individuals, which is approximately 0.29% of the world population of the species.

**3.2 Introduction**

The total world population of Kittlitz's Plover prior to 2009 (in its entire geographical range in Africa and Madagascar) was estimated at 140,000 to 185,000 individuals, with birds in the Eastern, Central and Southern African region estimated at more than 100,000 individuals (Delany and Scott, 2002). These estimates have been revised to range from 100,000 to 400,000 in the entire species geographical range, while the Eastern, Central and Southern African population is maintained at over 100,000 individuals (Delaney *et al.,* 2009).

The species makes seasonal movements that are not well understood, but seem to be regulated by seasonal rainfall with birds leaving during rains and flooding (Del Hoyo *et al.,* 1992; Urban *et al.,* 1986). The longest distance covered by any individual of the species estimated from ring recoveries is 332 km (Underhill *et al.,* 1999; Tree et al., 1997; Lipshutz *et al.,* 2011). Lakes Nakuru and Elmenteita are important sites for the conservation of waterbirds in Kenya and are designated as Ramsar Sites and Important Bird Areas (IBAs) (Fanshawe and Bennun, 1991).

The Kittlitz's Plover is among the few shorebird species known to breed at these two sites (Kutilek, 1974). The patterns of distribution and abundance of the species between marshes and open shores at Lake Nakuru are known to be influenced by the lake water levels (Owino, 2002). This chapter explores the dynamics of the numbers, distribution and movements of Kittlitz's Plover at these two sites.

## 3.3 Materials and methods

### 3.3.1 Counting individuals, nests, eggs and chicks

Between March 2005 and August 2006, structured direct counts of Kittlitz's Plover were conducted following the protocols by (Perennou, 1991). Total counts of the individuals of the species in Lakes Elmenteita and Nakuru were done once a month. The number and distribution of individuals, adults, young, nests and eggs that were encountered were recorded by sections per site. GPS coordinates of all these observations were also recorded.

### 3.3.2 Analysis of count data of individuals, nests, eggs and chicks

These numbers were converted to densities as number per km of shoreline length. The different sections of the lake though initially divided to conveniently ease the counts were assessed and classified according to the habitat characteristics of the shoreline for Kittlitz's Plover (Figure 2.1 and 2.2). These data are analysed along with the count data collected for the period 1991 to 2006 from the National Waterbird Census programme (Nasirwa and Bennun, 2000) and rainfall data for the period 1986 to 2006 from the Nakuru Meteorological Station. These analyses are done to estimate population size, relative density, distribution, movement and seasonal and annual trends in numbers of the species. A comparison of these parameters between sections of each site and between the two sites is also assessed to determine the variation between sections and the sites as well as assess the habitat preference for the species.

## 3.4 Results

### 3.4.1 Number and distribution of Kittlitz's Plover at Lakes Nakuru and Elmenteita

The January and July count data for the period 1991 to 2006 are summarised in Appendix 4. The highest numbers for the species were counted at Lake Nakuru in January 2000 at 544 birds and 472 birds at Lake Elmenteita in January 2004. The highest combined total for the two sites was 668 birds in January 2000 when Lake Nakuru had 544 birds and Lake Elmenteita had 124 birds.

### 3.4.2 Shoreline characteristics and lengths of the different study section at Lakes Nakuru and Elmenteita

The shoreline section characteristics broadly fell into three types namely open, marshy and rocky. Some sections were a mosaic of these three categories which varied or were influenced by the water levels of the lake. The brief descriptions of shoreline lengths of the different sectors and their characteristics are summarised (Table 3.1).

**Table 3.1 Shoreline characteristics and length of the different sections of Lakes Nakuru and Elmenteita.**

| Site/Section | Shoreline description and characteristics | Length/km |
|---|---|---|
| Lake Nakuru | | |
| 1 | Open | 5.6 |
| 2 | Open | 5.3 |
| 3 | Open | 3.9 |
| 4 | Marshy/open | 5.2 |
| 5 | Marshy, open during low water levels | 6.9 |
| | **Total length of shoreline** | **26.9** |
| Lake Elmenteita | | |
| 1 | Open | 3.4 |
| 2 | Closed with rocky edges | 8.1 |
| 3 | Marshy, open during low water levels | 6.4 |
| 4 | Marshy, open during low water levels | 4.0 |
| 5 | Closed rocky cliff-base, narrow shoreline habitat | 3.2 |
| | **Total length of shoreline** | **25.1** |

Generally, Lake Nakuru had a total shoreline length of 26.9 km, where open shoreline covered 14.8 km (5.6+5.3+3.9 = 14.8 km). A mosaic of open and marsh shoreline areas covered 5.2 km. Shoreline that was marshy but became open during low water level covered 6.9 km. Lake Elmenteita had a total shoreline length of 25.1 km where open shoreline covered 3.4 km, marshy but open during low water level covered 10.4 km (6.4+4.0 = 10.4 km), and rocky areas covered 11.3 km (8.1+ 3.2 = 11.3 km).

### 3.4.3 Analysis of shoreline length, characteristics and densities of Kittlitz's Plover at Lakes Nakuru and Elmenteita

Generally, there was higher habitat diversity in Lake Elmenteita than in Lake Nakuru (Table 3.1). Nearly 55.1% (((5.6+5.3+3.9)/26.9)x100) of the shoreline was open in Lake Nakuru compared to 13.5% ((3.4/25.1)x100) of the shoreline at Lake Elmenteita. The mean (±SD) density of Kittlitz's Plover (number per km of shoreline) in the different sections are summarised in Figure 3.1

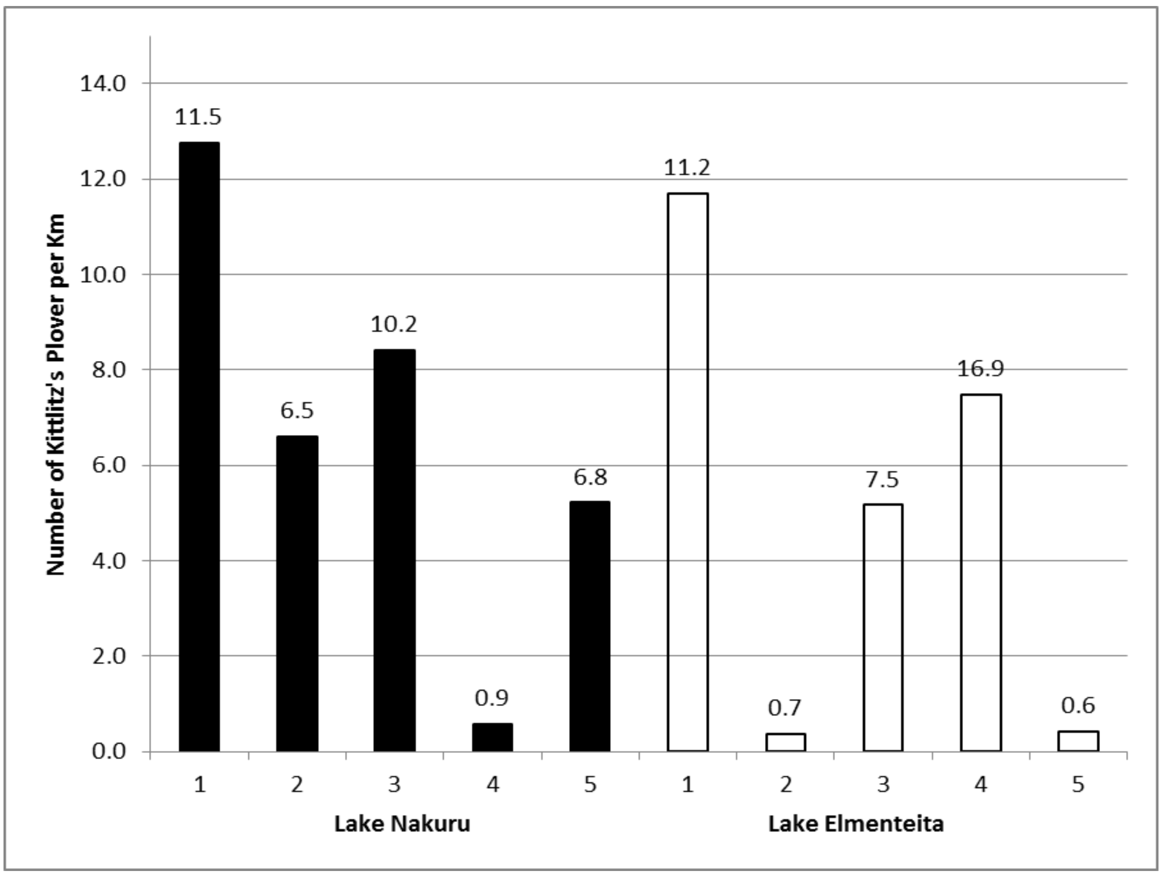



**Figure 3.1 Mean density of Kittlitz's Plover for the month of January in the different sections (1-5) of Lake Elmenteita (unshaded bars) and Nakuru (shaded bars) for the period 1991 to 2006.** (The densities are expressed in number per km of shoreline length. Numbers in the graph show SD).

### 3.4.4 Comparisons of Kittlitz's Plover densities across the different shoreline characteristics of Lakes Elmenteita and Nakuru

The mean densities of Kittlitz's Plover were higher at the open shore sites of each lake compared to the marshy shorelines. The marshy open sectors of the lakes had significant numbers of Kittlitz's Plover during periods of low lake water levels. However, these densities were highly variable as indicated by the large standard deviations (SD) perhaps due to disturbance, initiating local movements.

One-way ANOVA of Kittlitz's Plover densities against shoreline conditions revealed significant differences across all the sections ($F_{9,\ 150} = 4.032$, $P < 0.001$). The Bonferroni Test values for significant differences between sections are shown below (Table 3.2). The most notable difference in Kittlitz's Plover densities are between open and closed habitats as shown by the first three pair-wise section comparisons. The 95% confidence limits also revealed large margins in the differences in Kittlitz's Plover densities between the sites.

**Table 3.2 Bonferroni Test showing significant differences in mean densities of Kittlitz's Plover between sections at Lakes Nakuru (NKU) and Elmenteita (ELT)**

| | | | | 95% Confidence Interval Bound | |
|---|---|---|---|---|---|
| (I) Section | (J) Section | Mean Difference (I-J) | *P* value | Lower | Upper |
| ELT2 | NKU1 | 12.39 | 0.006 | 1.92 | 22.87 |
| ELT5 | NKU1 | 12.35 | 0.006 | 1.87 | 22.82 |
| NKU1 | NAKU4 | 12.18 | 0.007 | 1.71 | 22.65 |
| ELT1 | ELT2 | 11.33 | 0.020 | 0.86 | 21.80 |
| ELT1 | ELT5 | 11.28 | 0.021 | 0.81 | 21.75 |
| ELT1 | NKU4 | 11.11 | 0.025 | 0.64 | 21.59 |

There was no significant difference in the pooled density of Kittlitz's Plover between the two study sites ($F_{1, 158} = 1.232$, $P = 0.269$).

### 3.4.5 Temporal variations in the densities of Kittlitz's Plover in Lakes Elmenteita and Nakuru over 16 years.

The trend in densities of Kittlitz's Plover (number per km of shoreline length) for the period 1991 to 2006 at Lakes Nakuru and Elmenteita using the January counts data only are shown below (Figure 3.2).

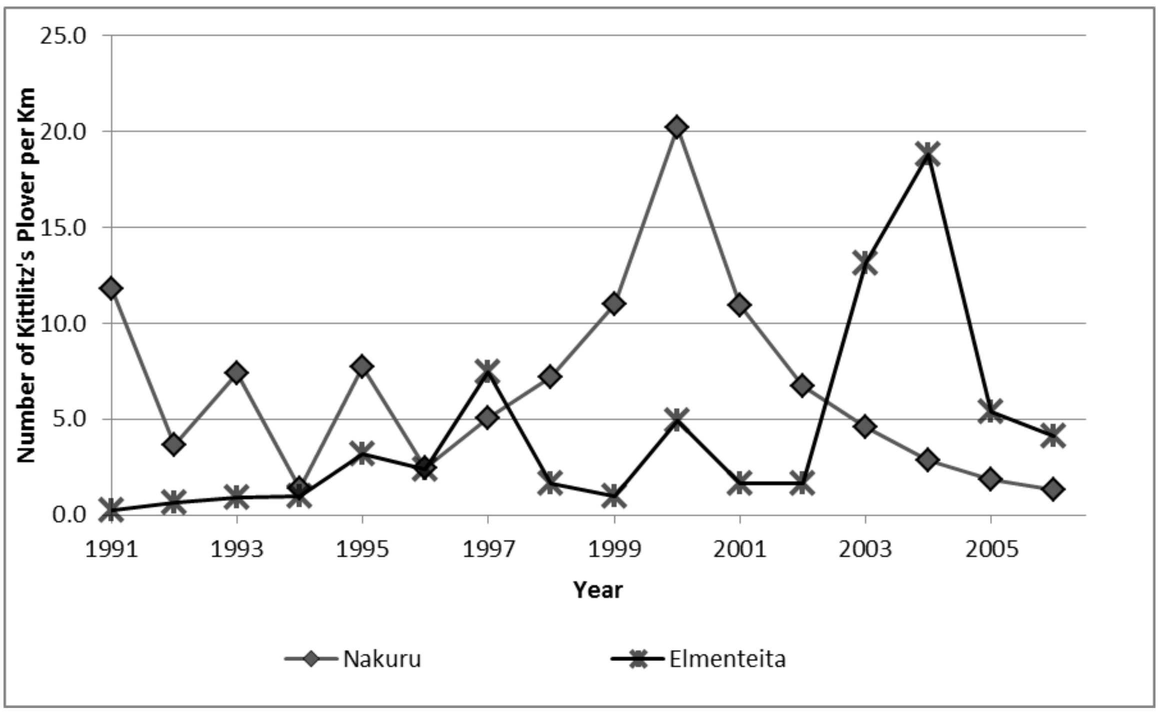



**Figure 3.2 Density of Kittlitz's Plover (number per km of shoreline) against years at Lakes Elmenteita and Nakuru (1991 to 2006).** (January count data).

The density of Kittlitz's Plover (numbers per km) were higher at Lake Nakuru during the period 1991 to 2002. The density became higher at Lake Elmenteita compared to Lake Nakuru during the period 2002 to 2006. Between 1997 and 2001, the Kittlitz's Plover population in Lake Nakuru increased considerably but steadily declined in the subsequent years when numbers of Kittlitz's started building-up in Lake Elmenteita.

Monthly numbers of Kittlitz's Plover during the 18 months of study (March 2005 to September 2006) fluctuated from a high of 179 individuals to a low of 22 individuals at Lake Elmenteita and 48 to zero at Lake Nakuru (Table 3.3).

**Table 3.3 Numbers of Kittlitz's Plover counted at Lakes Nakuru and Elmenteita between March 2005 and July 2006.**

| Year | Month | Lake Elmenteita | Lake Nakuru |
|---|---|---|---|
| 2005 | March | 71 | 18 |
| | April | 72 | 17 |
| | May | 76 | 15 |
| | June | 80 | 33 |
| | July | 79 | 41 |
| | August | 84 | 48 |
| | September | 88 | 46 |
| | October | 79 | 41 |
| | November | 45 | 35 |
| | December | 36 | 30 |
| 2006 | January | 89 | 35 |
| | February | 93 | 31 |
| | March | 89 | 11 |
| | April | 96 | 3 |
| | May | 87 | 1 |
| | June | 117 | 1 |
| | July | 179 | 0 |
| | August | 22 | 0 |

The Numbers of Kittlitz's Plover were higher at Lake Elmenteita compared to Lake Nakuru. When the numbers of Kittlitz's Plover were high in June and July 2006 in Elmenteita, birds were virtually absent in Lake Nakuru.

A linear regression of the total monthly densities (numbers per km) of Kittlitz's Plover between the two sites ($y = -0.1244x + 1.2466$, $r^2 = 0.0658$, $F_{1, 15} = 1.126$, $P = 0.304$) was negative but not significant (Figure 3.3).

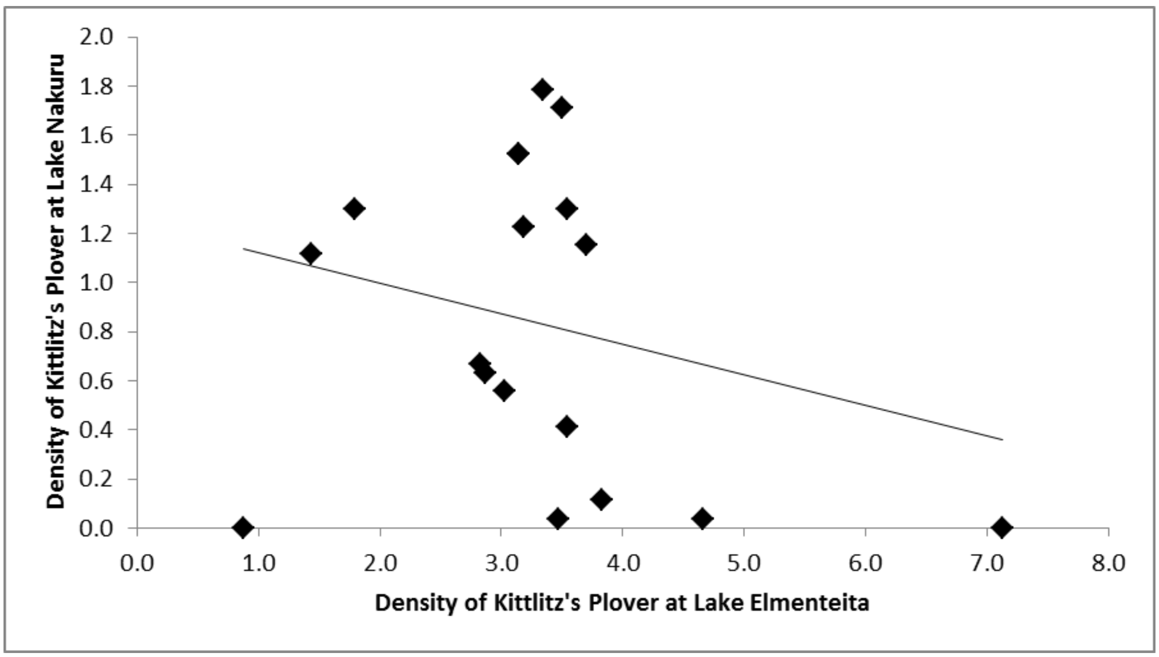



**Figure 3.3 Regression of monthly densities of Kittlitz's Plover at Lake Nakuru against Lake Elmenteita from March 2005 and August 2006.** ($y = -0.1244x + 1.2466$, $r^2 = 0.0658$, $F_{1, 15} = 1.126$, $P = 0.304$; not significant).

At Lake Elmenteita, the birds were more abundant in the areas of open shores (i.e. the northern shore (section 1)) and the southern shore (sections 3 and 4) shorelines. At Lake Nakuru the long term data for the months of January (1991 to

2006) showed abundance of the plovers in both marshy and open shore areas. However, mapping the monthly distribution of birds during the study period depicted a distribution of higher abundance in the open shore (that is in the Western (section 1) and South-Western (section 2)) areas (Figure 3.4).

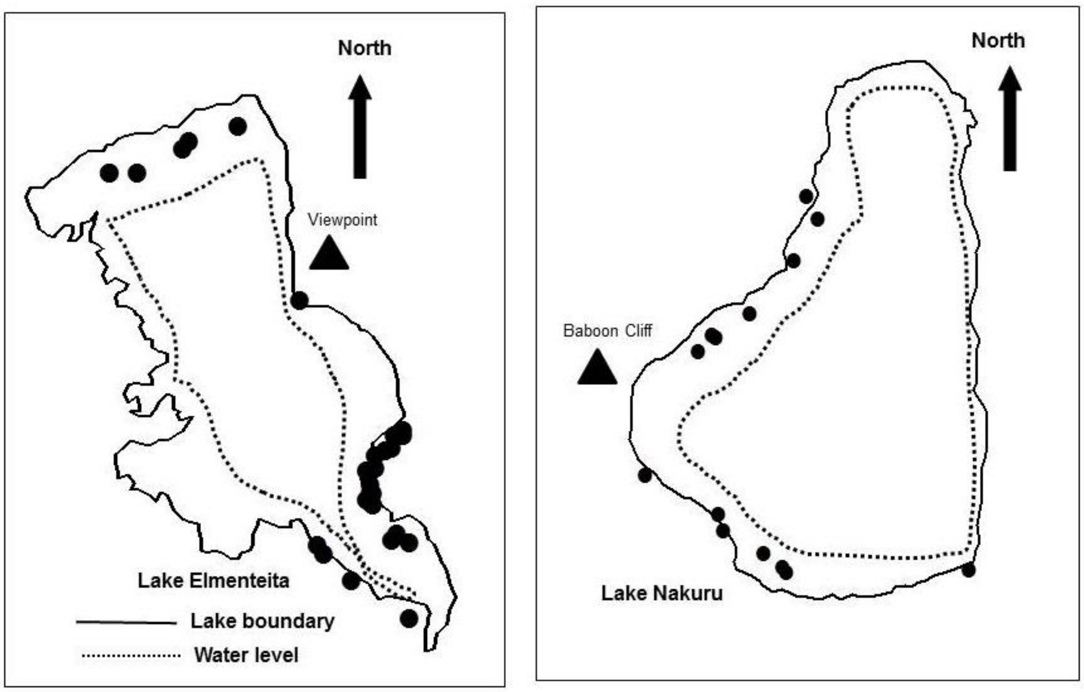



**Figure 3.4 Distribution of Kittlitz's Plover sighted at Lakes Elmenteita and Nakuru during the study period (March 2005 to August 2006).** The dots represent presence.

The mean (+var) number of adult Kittlitz's Plover per km of shoreline at Lake Elmenteita (3.3 ± 1.73) was significantly higher ($F_{1, 34}$ = 50.356, $P$ = 0.001) than at Lake Nakuru (0.8 ± 0.41) during the 18-month study period (Figure 3.5).

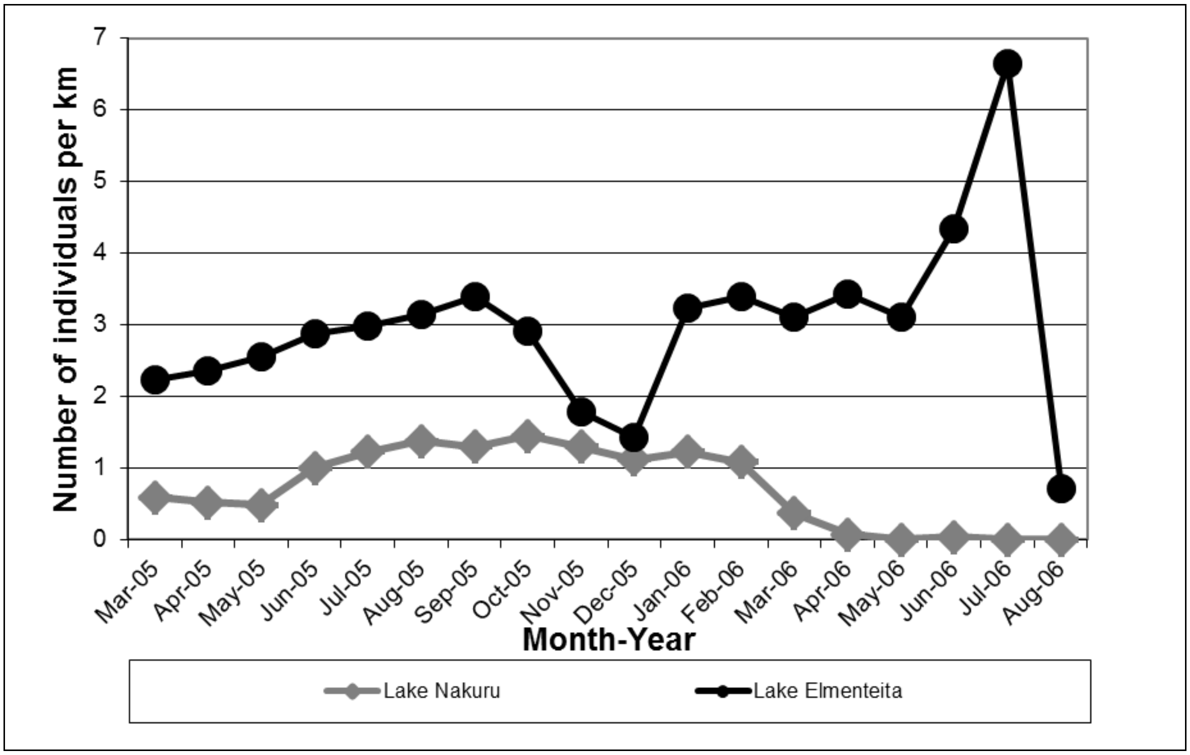



**Figure 3.5 Density of adult Kittliz's Plover at Lakes Nakuru and Elmenteita between March 2005 and August 2006.**

In 2005, the monthly densities of the adult birds at Lake Elmenteita declined from September to the same level as at Lake Nakuru and then bounced back to higher densities from January 2006. For Lake Nakuru, the densities in 2005 remained at low levels to March 2006, and then declined steadily up to the end of the study period.

Young birds were encountered in both sites throughout the year except in December 2005 (Figure 3.6). The trend indicated breeding activity running throughout the year with the exception of December.

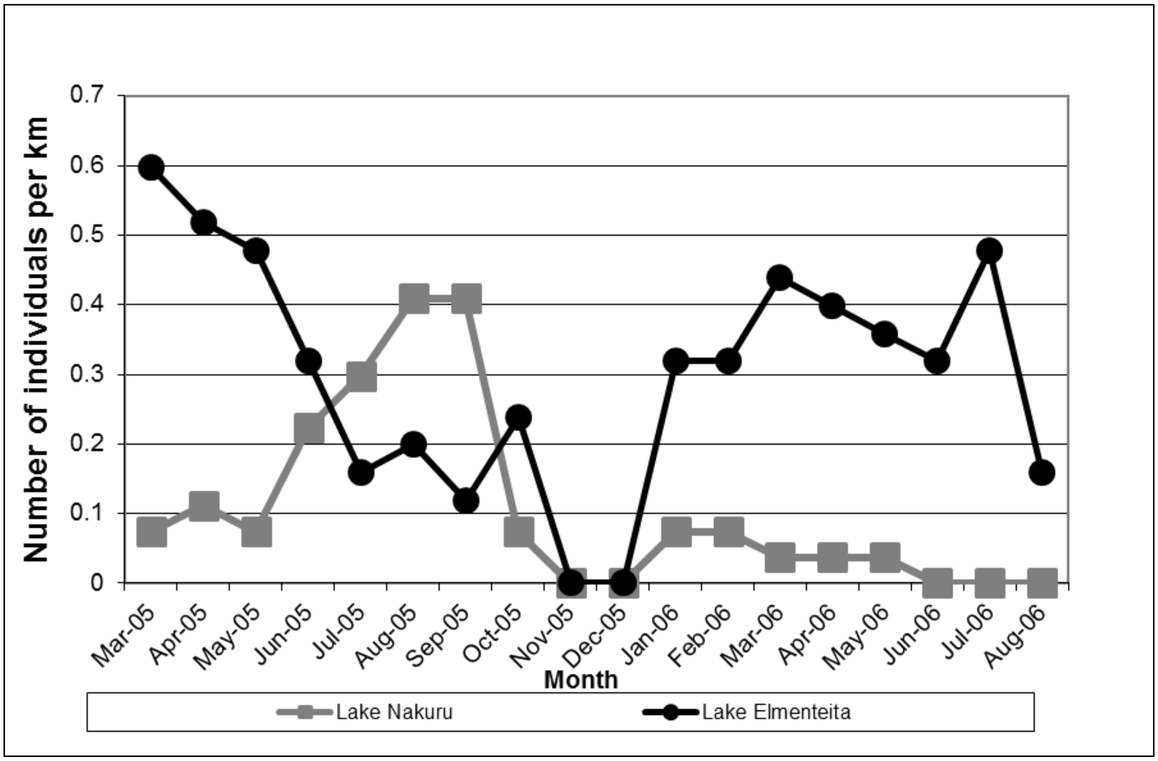



**Figure 3.6 Densities of juvenile Kittliz's Plover at Lakes Nakuru and Elmenteita between March 2005 and August 2006.**

The numbers of nests100% (32/32), eggs 100% (58/58) and chicks 97% (64/66) were mainly found in the period between May to September. This indicates that this period was the peak breeding season for Kittlitz's Plover at Lakes Nakuru and Elmenteita in 2005 and 2006 (Figure 3.7).

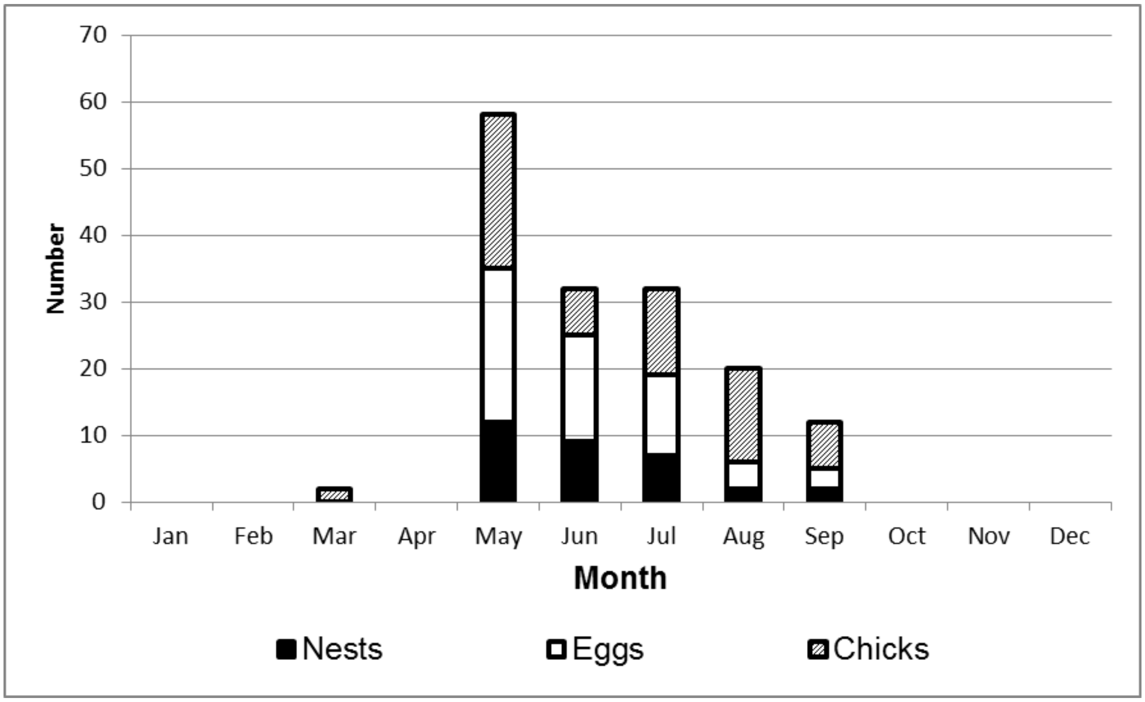



**Figure 3.7 Monthly numbers of nests, eggs and chicks at Lakes Nakuru and Elmenteita combined for the period 2005 and 2006.**

**3.4.6 Analysis of rainfall data at Lakes Nakuru and Elmenteita**

Assessments of long term average rainfall for 1986 to 2004, show that the main wet season (long rains) covers the period from April to May and the minor wet season (short rains) is during the months of October to November (Figure 3.8).

The trend in rainfall shows some slight shifts from the long-term average during the study period. The years 2005 and 2006, had quantities of rainfall below the long term (1986 to 2004) average rainfall in the months of January to March and June to August. The wet season during the long rains period of April to May was wetter than average and the peak which is normally in April, had shifted to May in

2005 and 2006. The wet season during the short rains, August to October, was also wetter with the peaks more delayed during the study period.

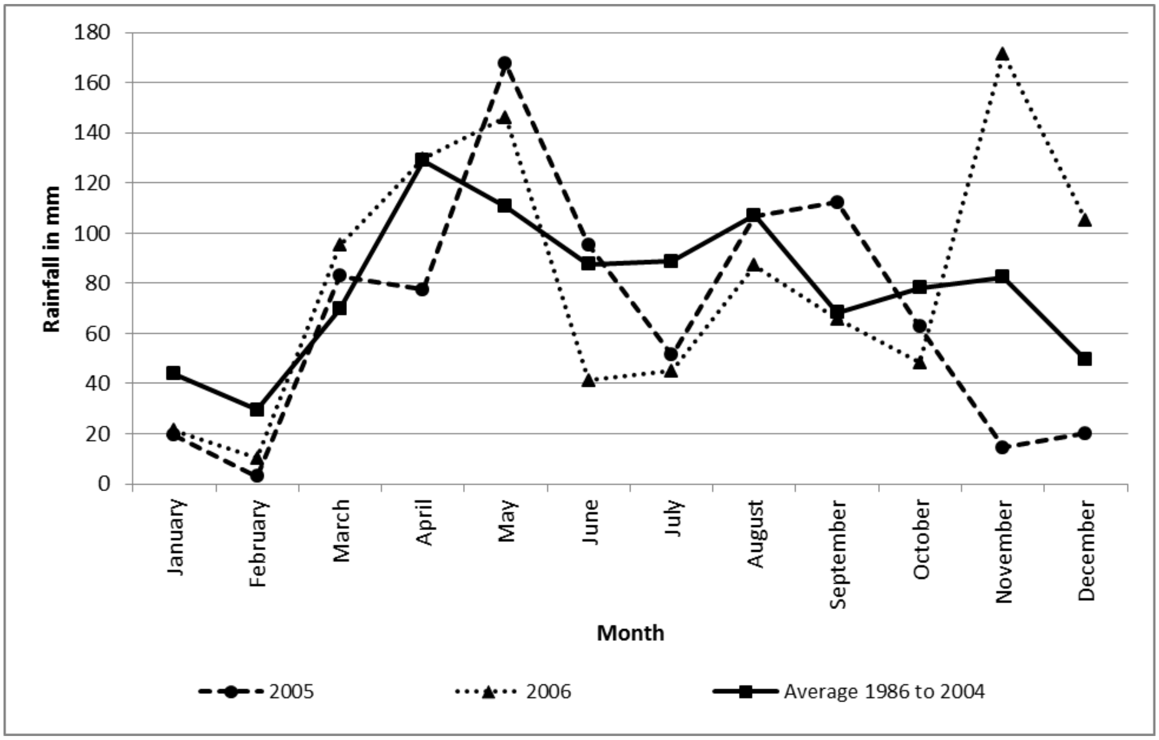



**Figure 3.8 Mean monthly rainfall for the period 1986 to 2004 and monthly rainfall for the years 2005 and 2006 from Nakuru Meteorological Station.**

The peak for the long term average was in August, but rainfall levels remained over 60 mm monthly. In 2005 the peak rainfall was in September from where it declined all the way to December. In 2006, the peak was further delayed to November with a relatively dry October in both 2005 and 2006.

### 3.4.7 Relationship between rainfall and Kittlitz's Plover numbers at Lakes Nakuru and Elmenteita

On the ground, Lake Nakuru experienced wetter conditions compared to Lake Elmenteita which had drier conditions. This led to less exposed shoreline areas at Lake Nakuru and increased exposed shoreline areas at Lake Elmenteita. Even though the rainfall patterns showed month by month seasonal shifts the total annual rainfall during the study period remained within the long term mean range (Figure 3.9).

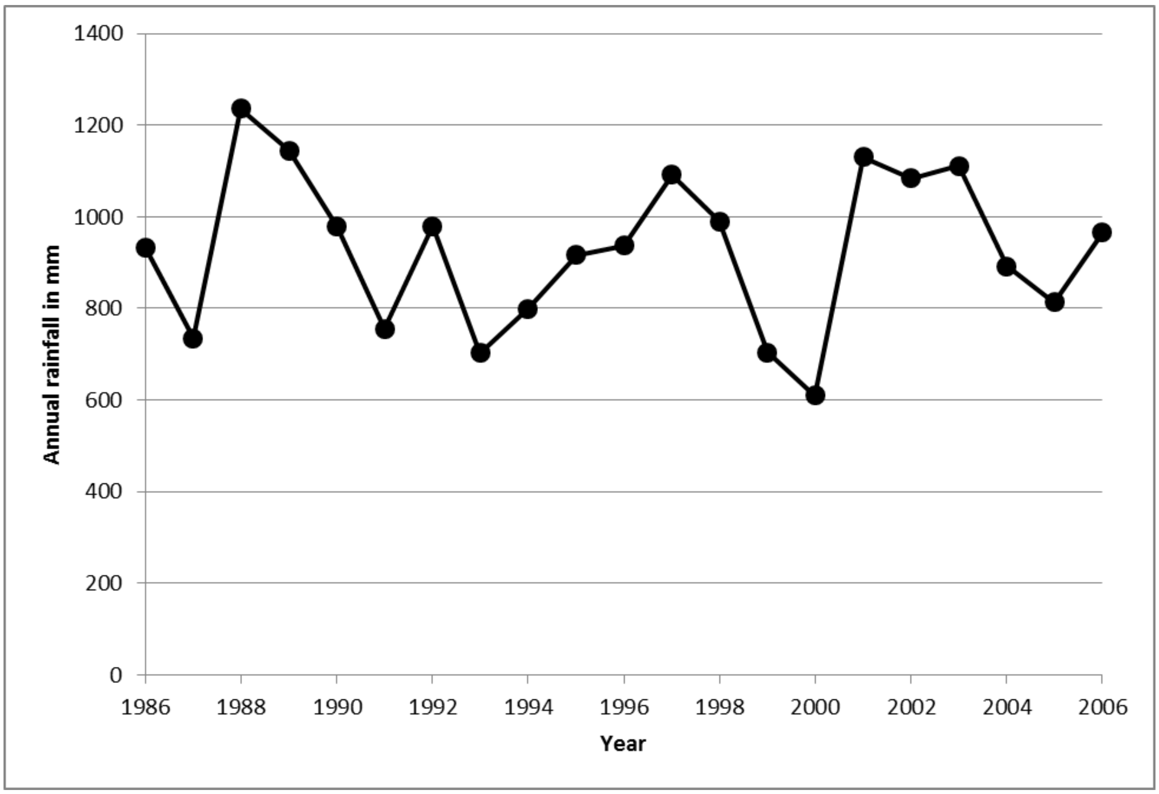



**Figure 3.9 Annual rainfall data for the period 1986 to 2006 from Nakuru Meteorological Station.**

As the graph depicts, 2006 was a wetter year than 2005, hence the density of Kittlitz's Plover in the study area was expected to decline as predicted by their known behaviour to move away during rains. General observations and climatic conditions indicate that Lake Nakuru is normally wetter than Lake Elmenteita, leading to expectations of higher declines in densities of birds at Lake Nakuru compared to Lake Elmenteita (Figure 3.10).

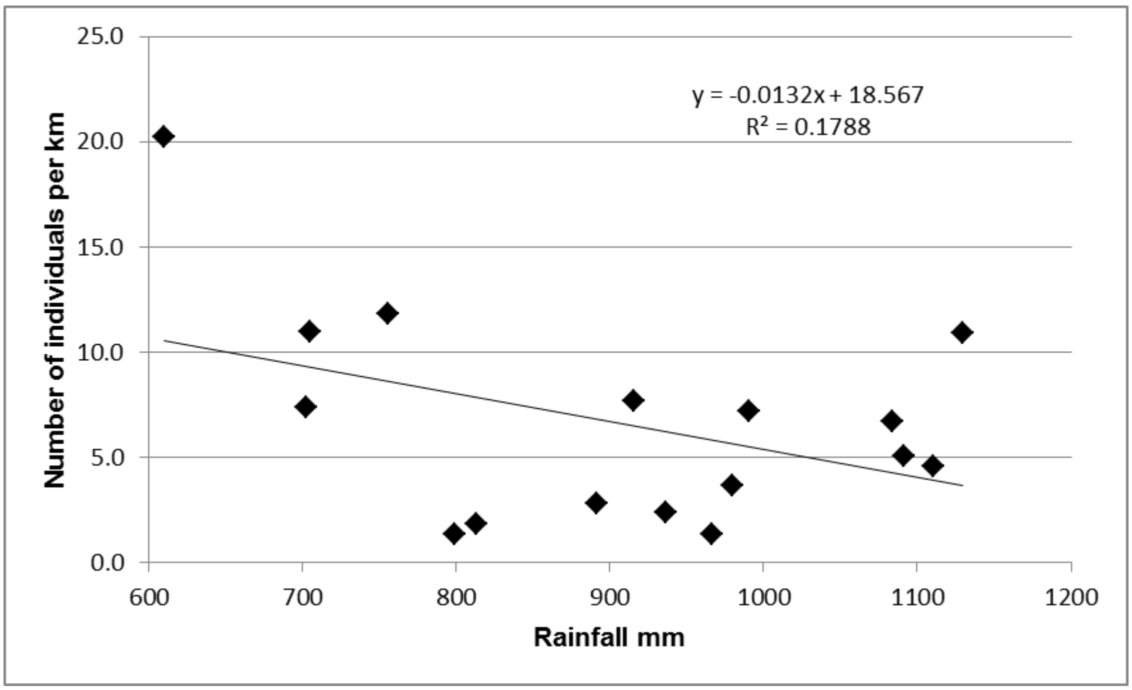



**Figure 3.10 Regression of density of Kittlitz's Plover against annual rainfall at Lake Nakuru for the period 1991 to 2006.** (Data used is for the January months only).

The linear regression of Kittlitz's Plover densities against annual rainfall at Lake Nakuru produces an indirect relationship (y = -0.01x + 18.6, $r^2$ = 0.18; $F_{1,\ 14}$ = 3.049, $P$ = 0.103, ns). The linear regression of annual rainfall against Kittlitz's

Plover densities at Lake Elmenteita produced a direct relationship (y = 0.01x – 1.74, $r^2 = 0.04$; $F_{1, 14} = 0.643$, $P = 0.436$, ns) (Figure 3.11). The linear regression trends for rainfall and Kittlitz's Plover densities at both Lakes Nakuru and Elmenteita were not significant.

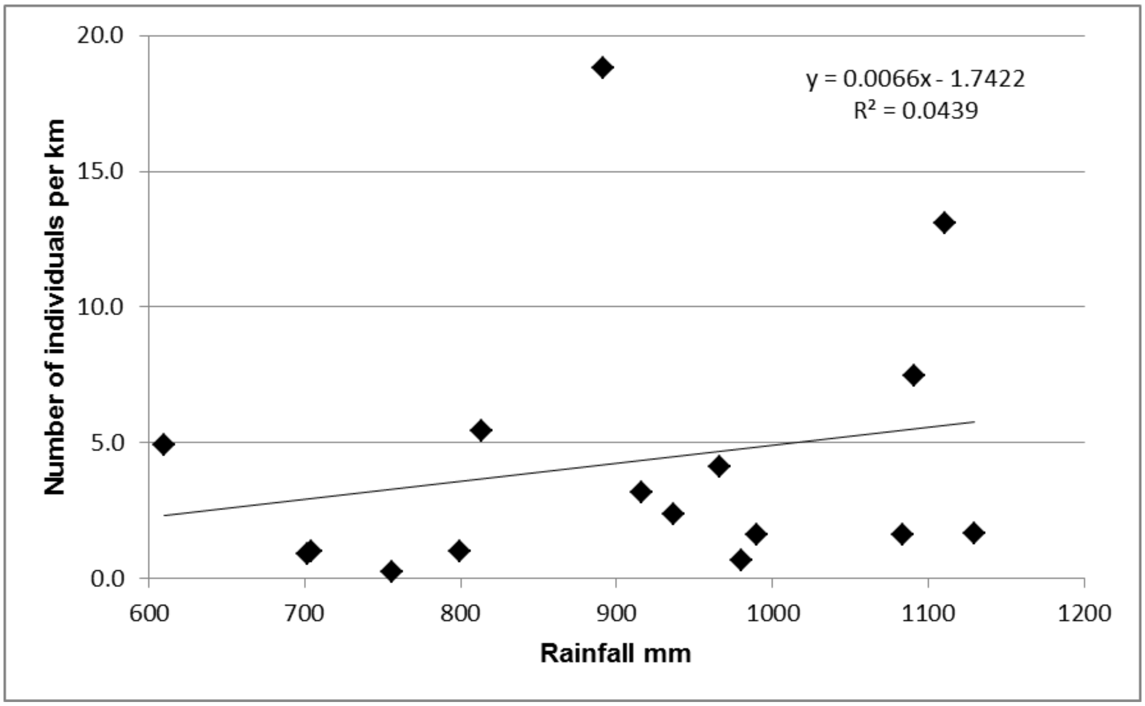



**Figure 3.11 Regression of density of Kittlitz's Plover against annual rainfall at Lake Elmenteita for the period 1991 to 2006.** (Data used is for the January months only).

The predictor variable (rainfall) explained 18% of Kittlitz's Plover density variability in Lake Nakuru and only 4% in Lake Elementeita. Kittlitz's Plover densities declined with increasing rainfall in Lake Nakuru while they increased with increasing rainfall at Lake Elementeita.

### 3.5 Discussion

The distribution of Kittlitz's Plover numbers in the different sections of the sites indicated that the species was more abundant in sections that had open shorelines including mudflats and marshy areas with short sedges and grass clumps. They were less abundant in areas that had closed shorelines (i.e with a rock substrate or dense fringing vegetation). During periods of high water level the species would be restricted to the open shoreline areas of the two sites. However during the drier period when water levels were low the species would be found in all sections around the lake occupying exposed areas of mudflats that result from the draw-down by the water levels.

The average Kittlitz's Plover population size was 178 birds in Lake Nakuru and 107 birds in Lake Elmenteita. The average density of Kittlitz's Plover (numbers per km shoreline) is 7 birds /$km^{-1}$ of shoreline length for Lake Nakuru and 4 birds /$km^{-1}$ of shoreline length at Lake Elmenteita. These numbers translate to an average of 285 birds for the two sites combined which is approximately 0.29% of the world population. The numbers at both sites fluctuated from a low of 62 birds (January 1994) to a high of 668 birds (January 2000).

Kenya falls within the range of the race *Charadrius pecuarius pecuarius*, who's 1% population size is 2,500 birds (Delaney *et al.,* 2009). Hence, Lakes Nakuru and Elmenteita do not qualify as internationally important site for the conservation of the species. However, as breeding sites for the species, their contribution to the global population cannot be overlooked. These sites experience sporadic influx of non-breeding birds, whose origin is unknown, but presumed to be from the tropical regions of Africa. Their numbers tend to decrease and stabilise during the breeding period, but this trend may depend on rainfall patterns, temperature and water levels at these sites or at alternative sites that the birds use. This support for individuals from other parts of Africa make these sites an important part of a network of sites for the species.

Even though young birds were observed in the study area during the entire study period, the data on nests, eggs and chicks found indicate that the peak breeding period for the years 2005 and 2006 was May to September. Taking this point further, would suggest that most individuals that stay during this period (May to September) form the breeding population. The seasonal fluctuations in population size and densities reflect breeding patterns and local movements (Lipshutz *et al.,* 2011). However, distinguishing residents from itinerant birds is difficult with partially migratory species like the Kittlitz's Plover (Lipshutz *et al.,* 2011).

The main peak in rainfall period for the two years (2005 and 2006) were extensive, compared to the long term trend, i.e. extending from April to May. Interestingly on the ground, Lake Nakuru was much wetter with less open shore than Lake Elmenteita which was relatively drier with extensive open shores throughout 2006. This may explain the increase in numbers and breeding activities of Kittlitz's Plover at Lake Elmenteita and a decrease of the same at Lake Nakuru between the two years.

Lake Nukuru is virtually wetter compared to Lake Elmenteita, hence some increase in moisture may make the conditions unfavourable for the species triggering movement of individuals away from the site. On the other hand, some moderate increase in moisture at Lake Elmenteita, which is relatively drier, may trigger movement of some individuals of the species into the site.

The densities of Kittlitz's Plover in the two sites were inversely related, indicating that the conditions for the species to move into and from either site were inversely related. However, no recoveries or controls from the ringing data supported movement of the birds between the two sites. The numbers strongly point to an open system where birds moving into and out of these two sites come from other sites rather than between them. However the movement of the birds between the two sites cannot be ruled out. A long term ringing program for the species would help shed more light on the movement patterns of Kittlitz's Plover in the two sites.

The monthly trend data from March 2005 to August 2006, show that successful breeding makes the birds to stay, hence increasing the resident population. This suggests that improving environmental conditions that promote breeding, especially during the peak breeding period (i.e. from May to September), for the species is critical and an important step towards aiding the species increase its numbers at the two sites. This would be achieved by ensuring that there are sufficient areas that are safe from flooding and human impact on the shoreline for the species to place its nest and breed successfully.

# CHAPTER 4: DIVERSITY AND ABUNDANCE OF INVERTEBRATES AS POTENTIAL FOOD OF KITTLITZ'S PLOVER IN LAKES NAKURU AND ELMENTEITA

## 4.1 Abstract

To fully assess the suitability of Lakes Elmenteita and Nakuru as suitable habitat for the Kittlitz's Plover, it is important to assess the abundance and availability of its food base. Kittlitz's Plover mainly feed on invertebrates. Apparently, there is a lack of information on the diversity and abundance of invertebrates in the Kittlitz's Plover habitat around these two lakes. Hence, pitfall traps were used to assess the abundance and distribution of invertebrates as Kittlitz's Plover available food in Lakes Nakuru and Elmenteita. Fourteen taxonomic families in six orders namely Araneae, Coleoptera, Dermaptera, Diptera, Hymenoptera and Hemiptera were captured. Coleoptera comprising 96% and 89% of the invertebrates captured at Lakes Elmenteita and Nakuru respectively, was the most abundant. Hemiptera comprising less than 1% at both sites was the least abundant. The genus *Acupalpus*, with 63% abundance, dominated the samples from Lake Nakuru, while *Heterocerus* with 87% abundance, dominated the samples from Lake Elmenteita. *Labidura riparia* was higher in abundance in most sections of Lake Nakuru compared to Lake Elmenteita. The distribution and abundance of the other orders was not different across the two sites and the sections. Bias by the pitfall trap obscured the true presence, abundance and distribution of some orders such as Diptera and Orthoptera. I recommend further studies using other methods to fill the gaps identified by this study including looking into the role of *Labidura riparia* in the diet and distribution of Kittlitz's Plover.

### 4.2 Introduction

Shorelines of lakes and water edges of rivers are dynamic habitats primarily because of alternating drying and wetting. Aquatic invertebrates tend to change in their diversity and abundance in relation to moisture gradient, amount of organic matter and type of substrate. Kittlitz's Plover prefers breeding around water bodies with wide barren shorelines (Tree *et al.,* 1997).

One factor that may affect reproductive rates is the quality of foraging habitat for pre-fledging chicks (Elias, Fraser, and Buckley 2000). The species is known to be carnivorous with a diet consisting of invertebrates including Coleoptera (beetles), Diptera (flies), Aranae (spiders), Hemiptera (bugs), Hymenoptera (wasps, bees and ants), Orthoptera (grasshoppers) as well as larvae of Lepidoptera (moths and butterflies), polycheate worms, crustaceans and molluscs — usually up to 40 mm long (Cramp *et al.,* 1983; Del Hoyo *et al.,* 1992; Hockey *et al.,* 2005; Tree, 1974; Urban *et al.,* 1986).

There is a dearth of information on the invertebrate species at Lakes Elmenteita and Nakuru, which may be potential prey for Kittlitz's Plover. However, there are few existing studies touching on specific species of invertebrates in the taxonomic orders listed as food for the Kittlitz's Plover in the study area. Furthermore, these studies do not document any information on distribution, diversity and abundance in the Kittlitz's Plover habitat (Baldizzone and van der Wolf, 2011; David, 2009; Leichtenfried and Shivoga, 1995; McCulloch *et al.,* 2008; Mavuti, 1975; Platnick and Murphy, 1987; Merkl *et al.,* 1993; Khamala, 1975; Shivoga, 2001). The objectives of this Chapter were to determine the distribution, diversity and abundance of invertebrates in the Kittlitz's Plover habitats in Lakes Elmenteita and Nakuru.

### 4.3 Materials and methods

#### 4.3.1 Invertebrate sampling

Between the 14th and 16th September 2006, thirty six and forty two pitfall traps were set-up in Lakes Nakuru and Elmenteita respectively (Figure 4.1).

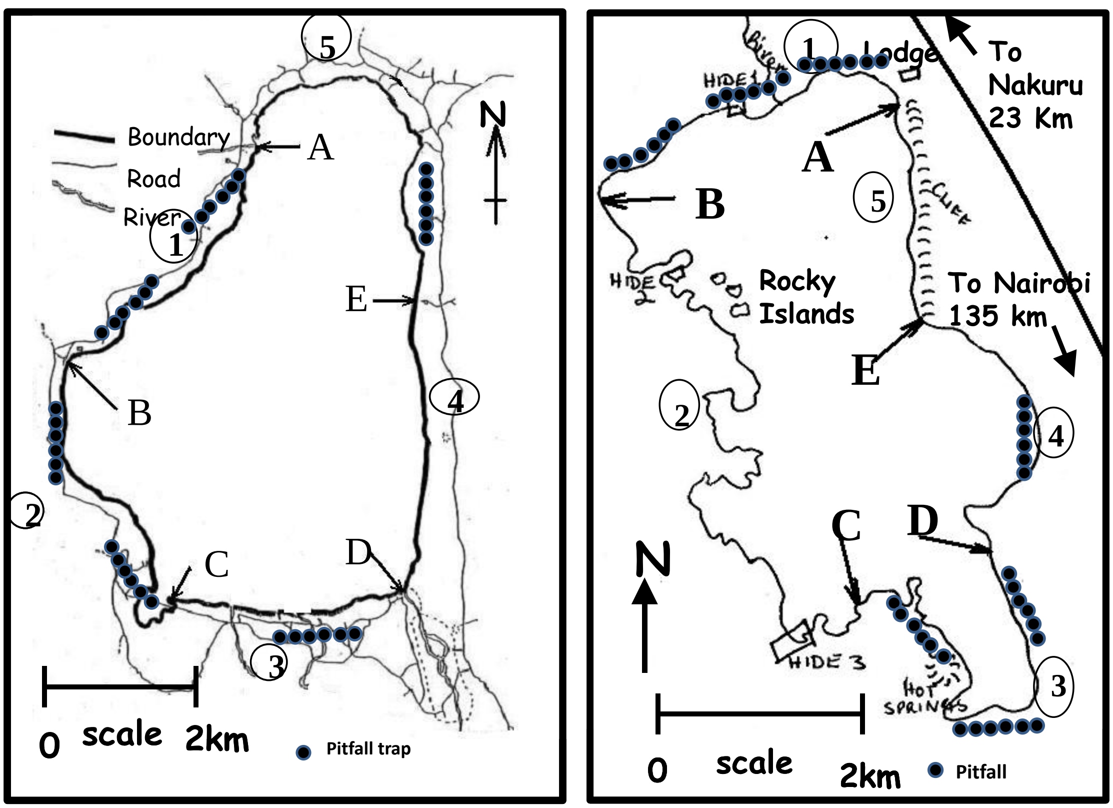


**Figure 4.1 Distribution of pitfall traps (solid dots) for invertebrate sampling around Lakes Nakuru and Elmenteita. (**Lake Nakuru (left) and Lake Elmenteita (right)).

The traps were made of plastic cylindrical cups measuring 70 mm in diameter and 100 mm in height. The cups were laid out in sets of six, where each cup was placed at a distance of two meters apart from each other. Each cup was dug into the ground such that the brim was at the same level with the ground (Figure 4.2).

**Figure 4.2 Collecting invertebrate samples from a pitfall trap at Lake Nakuru**. (Photo taken in September 2006).

The cups were halfway filled with water and a drop of detergent was added to break the surface tension of the water. This break in the surface tension of the water stopped the invertebrates from crawling or jumping out of the water trap.

The traps were monitored and harvested in such a ways as to gather samples of invertebrates captured at intervals of 24 hours, day (12 hours i.e. 06h00 to 18h00 daytime) and night (12 hour i.e. 18h00 to 06h00 overnight).

### 4.3.2 Invertebrate abundance and species richness

The invertebrates were harvested for 12 hours — day, 12 hours — night and 24 hours, giving a total of 48 hours. The catches had sporadic variation in that some traps would catch nothing or a few invertebrates in the 24 hour intervals, but caught high numbers of invertebrates in the twelve hour intervals. To reduce this irregularity and variation, the numbers of invertebrates caught were pooled for the 48 hour time period per trap. Based on the habitat assessments, the data were collated into sections and traps in the same sections pooled. The sections were as follows:-

1. ELM1 the northern section, i.e. from point A to B (Section 1).
2. ELM2 the southern section, i.e. also from point C to E (Sections 3 and 4).
3. NAK1 the western section i.e. from point A to B (Section 1).
4. NAK2 the south-western section i.e. from B to C (Section 2).
5. NAK3 the southern section i.e. from point C to D (Section 3).
6. NAK4 the northern section i.e. from E to A (Section 5)

## 4.4 Results

### 4.4.1 Species richness, abundance and distribution of invertebrates at Lakes Elmenteita and Nakuru

The invertebrates captured were identified, counted and summarised as the average number per set of six traps per site. They fell into six taxonomic orders and fourteen families. The orders were Araneae, Coleoptera, Dermaptera, Diptera, Hymenoptera and Hemiptera. Coleoptera was the most dominant order in the samples from both sites Lakes Elmenteita and Nakuru at 95% and 85% in abundance respectively. Hemiptera was the least abundant with only two items, all from Lake Elmenteita, being counted from the entire samples (Table 4.1). The genus *Acupalpus* dominated the samples from Lake Nakuru, while *Heterocerus* dominated the samples from Elmenteita.

**Table 4.1 Abundance of invertebrates captured per species using pitfall traps at Lakes Elmenteita and Nakuru in September 2006.** (The average numbers based on individuals caught per a set of six traps).

| Order | Family | Species | Lake Elmenteita | Lake Nakuru |
|---|---|---|---|---|
| Araneae | UNIDENTIFIED | unidentified spiders | 5.1 | 5.0 |
| Coleoptera | Carabidae | *Acupalpus columbinus* | 0.0 | 63.2 |
| | | Acupalpus natalicus | 0.0 | 296.0 |
| | | *Acupalpus sp*. | 0.0 | 44.2 |
| | Cicindelidae | *Lophyra neglecta* | 28.9 | 24.2 |
| | Coccinelidae | *Hippodamia variagata* | 0.0 | 0.3 |
| | Heroceridae | *Heterocerus sp*. | 803.4 | 133.8 |
| | Scarabacidae | *Aphodius sp.* | 0.0 | 0.2 |
| | Staphylinidae | *Zyras sp.* | 52.9 | 10.2 |
| | Tenebrionidae | *Zophosis punctata* | 1.3 | 0.3 |
| Dermaptera | Forficulidae | *Labidura riparia* | 33.9 | 58.3 |
| Diptera | Ceratopogonidae | unidentified sp. | 1.0 | 2.0 |
| | Muscidae | *Lispe sp.* | 1.7 | 1.7 |
| Hemiptera | Pentatomidae | *Gynenica sp.* | 0.3 | 0.0 |
| Hymenoptera | Formacidae | *Dorylus Molestus* | 2.0 | 0.0 |
| | Formacidae | *Tetramorium sp.* | 0.3 | 0.0 |
| | Vespidae | *Icaria sp.* | 0.3 | 1.7 |
| | | **Total** | **931** | **641** |

Some of the invertebrates captured could not be identified to the species level; hence the analysis of abundance was done at the taxonomic order level (Table 4.2). Where it is not possible to identify biological collections to species, other taxonomic groups may be used in estimating diversity and abundance (Brower *et al.,* 1998).

**Table 4.2 Relative abundance of invertebrates by shoreline sections at Lakes Elmenteita and Nakuru.** (n = number of sets of six pitfall traps).

| Site/strata | Order | n | Total | Average |
|---|---|---|---|---|
| Lake Elmenteita | | | | |
| ELM1 | Araneae | 3 | 8 | 2.7 |
| | Coleoptera | 3 | 3542 | 1180.7 |
| | Dermaptera | 3 | 118 | 39.3 |
| | Diptera | 3 | 11 | 3.7 |
| | Hemiptera | 3 | 2 | 0.7 |
| | Hymenoptera | 3 | 1 | 0.3 |
| ELM2 | Araneae | 4 | 28 | 7.0 |
| | Coleoptera | 4 | 2663 | 665.8 |
| | Dermaptera | 4 | 119 | 29.8 |
| | Diptera | 4 | 8 | 2.0 |
| | Hemiptera | 4 | 0 | 0.0 |
| | Hymenoptera | 4 | 17 | 4.3 |
| Lake Nakuru | | | | |
| NAK1 | Araneae | 2 | 11 | 5.5 |
| | Coleoptera | 2 | 1576 | 788.0 |
| | Dermaptera | 2 | 190 | 95.0 |
| | Diptera | 2 | 9 | 4.5 |
| | Hemiptera | 2 | 0 | 0.0 |
| | Hymenoptera | 2 | 5 | 2.5 |
| NAK2 | Araneae | 2 | 3 | 1.5 |
| | Coleoptera | 2 | 1479 | 739.5 |
| | Dermaptera | 2 | 83 | 41.5 |
| | Diptera | 2 | 12 | 6.0 |
| | Hemiptera | 2 | 0 | 0.0 |
| | Hymenoptera | 2 | 5 | 2.5 |
| NAK3 | Araneae | 1 | 1 | 1.0 |
| | Coleoptera | 1 | 297 | 297.0 |
| | Dermaptera | 1 | 19 | 19.0 |
| | Diptera | 1 | 1 | 1.0 |
| | Hemiptera | 1 | 0 | 0.0 |
| | Hymenoptera | 1 | 0 | 0.0 |
| NAK4 | Araneae | 1 | 15 | 15.0 |
| | Coleoptera | 1 | 82 | 82.0 |
| | Dermaptera | 1 | 58 | 58.0 |
| | Diptera | 1 | 0 | 0.0 |
| | Hemiptera | 1 | 0 | 0.0 |
| | Hymenoptera | 1 | 0 | 0.0 |

### 4.4.1 Species diversity of invertebrates at Lakes Elmenteita and Nakuru

The species diversity of invertebrates was higher at Lake Nakuru (Simpsons index of Diversity = 0.72 and Shannon-Weiner index *H* = 1.60) compared to Lake Elmenteita (Simpsons index of Diversity = 0.25 and Shannon-weiner index *H* = 0.59). Comparisons of the abundance of these taxonomic orders were significantly different for Dermaptera ($X^2$ = 132.15, df = 100, P = 0.017) among the sections of the sites. The abundance of the other orders was not significantly different among sections. Also the abundance of all the six orders' was not significantly different between Elmenteita and Nakuru (Table 4.3 and Table 4.4).

**Table 4.3 Spearman Chi-Square Test comparing abundance of invertebrate orders between sections of the sites at Lakes Nakuru and Elmenteita.**

| Invertebrate Order | $X^2$ | df | *P* value | Sample size (n) |
|---|---|---|---|---|
| Coleoptera | 335.29 | 315 | 0.207 | 78 |
| Dermaptera | 132.15 | 100 | 0.017 | 80 |
| Araneae | 31.99 | 25 | 0.158 | 73 |
| Hemiptera | 6.77 | 5 | 0.238 | 73 |
| Hymenoptera | 23.32 | 20 | 0.273 | 74 |
| Diptera | 19.85 | 15 | 0.178 | 75 |

**Table 4.4 Spearman Chi-Square Test comparing the abundance of invertebrate orders between Lake Nakuru and Lake Elmenteita.**

| Invertebrate Order | $X^2$ | df | *P* value | Sample size (n) |
|---|---|---|---|---|
| Coleoptera | 67.3 | 63 | 0.333 | 78 |
| Dermaptera | 25.0 | 20 | 0.203 | 80 |
| Araneae | 5.0 | 5 | 0.412 | 73 |
| Hemiptera | 1.8 | 1 | 0.181 | 73 |
| Hymenoptera | 3.7 | 4 | 0.447 | 74 |
| Diptera | 2.2 | 3 | 0.527 | 75 |

### 4.5 Discussion

A diverse community of invertebrates were available as potential food for the Kittlitz's Plover. Coleoptera followed by Dermaptera were the most abundant in both sites. In the order Coleoptera, *Lophyra neglecta* a species of small tiger beetles, was among the species that were occasionally observed being taken by the Kittlitz's Plover during foraging observations. Invertebrates in the order Diptera were also observed being eaten by Kittlitz's Plover during foraging observations. However, from the pitfall traps, their captures were quite low. This could be a bias with the pitfall traps towards capturing invertebrates that crawl like the Coleoptera and Dermaptera.

*Labidura riparia* in the family Forficulidae and the Order Dermaptera were higher in abundance in most sections of Lake Nakuru compared to Lake Elmenteita. Orthoptera (mainly crickets and grasshoppers) which also form the diet of the Kittlitz's Plover, were absent from the samples. This is as well is another bias caused by limitation of pitfall traps. Common methods for assessing diversity and abundance of Orthoptera are sweep-netting, transect counts and box-quadrats sampling (Schirmel *et al.,* 2010). A combination of these methods including sticky traps, baiting and suction traps could be used to compensate for pitfall trap biases observed in this study. However, working in the habitat of the Kittlitz's Plover at Lakes Nakuru and Elmenteita had the challenges of observing national park rules, dust in the air and considering the levels of human, vehicles and mammal disturbances. Hence this chapter provides some basic information on the abundance, diversity and distribution and of invertebrates based on pitfall trapping in Kittlitz's Plover habitats at Lakes Nakuru and Elmenteita. The significance of the role of *Labidura riparia* in the taxonomic order Dermaptera in the Kittlitz's Plover diet and distribution at these two sites may need further investigation.

# CHAPTER 5: FACTORS INFLUENCING FORAGING RATES OF KITTLITZ'S PLOVER AT LAKES NAKURU AND ELMENTEITA


## 5.1 Abstract

The conditions of foraging habitats have a strong bearing on the quality and quantity of food available to Kittlitz's Plover. These conditions also influence the foraging effort and success. Kittlitz's Plover feeding on mudflats at Lakes Nakuru (with high perceived human disturbance) and Elmenteita (with low perceived human disturbance) respectively were sampled to determine their foraging rates. The mean (±SE) Foraging Effort (i.e. number of steps made per individual in 30 seconds while foraging) at Lake Nakuru 34.83 ± 1.23 was significantly higher (Mann-Whitney U = 1373.5, n = 63, $P$ = 0.003) compared to Lake Elmenteita (30.95 ± 1.18). The mean (±SE) Foraging Efficiency (i.e. number of pecks made per individual in 30 seconds while foraging) at Lake Elmenteita 9.24 ± 0.52 (U = 1381.5, n = 63, $P$ = 0.003) and mean (±SE) Food Intake rate (i.e. number of swallows made per individual in 30 seconds while foraging) 4.70 ± 0.30 (U = 1506.5, n = 63, $P$ = 0.019) were significantly higher compared to Lake Nakuru where the mean Foraging Efficiency was 7.24 ± 0.52 and the Intake Rate was 3.70 ± 0.30 respectively. Overall birds at Lake Elmenteita had higher food availability, spent less energy feeding and hence the foraging success rate was higher compared to Lake Nakuru.

## 5.2 Introduction

Lakes Nakuru and Elmenteita are important sites for the conservation of waterbirds in Kenya and are listed as Ramsar sites and Important Bird Areas (Fanshawe and Bennun, 1991). Lake Elmenteita receives comparatively low tourist visitation, hence anthropogenic impacts on its shoreline remain relatively low. In addition to the effects of direct human disturbance on the reproductive behaviour of Kittlitz's Plover is the quality of foraging habitat for pre-fledged chicks (Elias *et al.,* 2000). Shorebirds view humans as predators. Consequently when people are present they attempt to reduce predation risk by spending time scanning for approaching humans. Increase in vigilance may reduce foraging rates in shorebirds (Burger and Gochfeld, 1991; Frid and Dill, 2002; Yasué, 2005). Kittlitz's Plover primarily use visual cues to hunt and search for food (Johnsgard, 1981). This Chapter assessed and compared the foraging rates of the Kittlitz's Plover at different shoreline sections of Lakes Elmenteita and Nakuru.

## 5.3 Materials and methods

### 5.3.1 Assessing Kittlitz's Plover foraging behaviour in groups

During the months of August and September 2005, visits were made to the different sections of Lakes Nakuru and Elmenteita with the aim of assessing the foraging behaviour of the Kittlitz's Plover. Using a pair of binoculars and spotting telescope, observations were made of individual plovers foraging in distinct groups and foraging rates estimated from foraging effort (number of steps), foraging efficiency (number of pecks) and intake (number of swallows) per unit time (Liley, 1999). During these observation periods, information on the selected study section of the shoreline and weather conditions (cloud cover, wind speed and temperature) were documented.

### 5.3.2 Sampling foraging of focal birds

Individual foraging Kittlitz's Plovers were randomly selected and observed for 30 second intervals using a telescope where the foraging effort, efficiency and intake rates were recorded. The duration of the observations was made short because of the high activity rate of Kittlitz's Plover. After an interval of one minute from the previous observation, a new individual was selected from the same group of foraging Kittlitz's Plovers and observations repeated. If the focal individuals changed activity from foraging (e.g. to preening or flew away), observations were terminated and another adult individual selected within the same group.

## 5.4 Results

### 5.4.1 Intra and interspecific interactions

Thirteen (Eight in Nakuru and five in Elmenteita) incidences of aggressive intraspecific interactions were recorded in the two sites during the study period. In these cases, pairs of Kittlitz's Plover fought and chased away conspecific intruders from their territory. The pair would do this, especially when they were incubating or leading young during foraging. Often parents leading young during foraging showed some aggression against conspecifics. They pushed them away to prevent them from coming close to their young. Some of the chases and fights were vicious to the point of tangling and rolling on the ground.

In situations where breeding activities were not evident, birds were observed in harmony flocks of from five, twelve, and seventeen to fifty individuals feeding, roosting and flying around together. At Lake Nakuru, Kittlitz's Plovers that ventured to feed in the adjacent grass habitats had frequently encountered aggression from the Red-capped Lark *Callandrella cineria*. In seven encounters observed between the two species, Kittlitz's Plover were chased from the grass habitats and back into the bare habitat on the shoreline. Three encounters were recorded where a Kittlitz's Plover in territorial behaviour chased away the Red-capped Lark from the bare shoreline habitats and into the grass zone. At Lake Elmenteita, similar interspecific interactions were recorded, but the other species was commonly the Fawn-coloured Lark *Mirafra africanoides*. The Fawn-coloured Lark chased the Kittlitz's Plover from the adjacent grassland areas of the Lake and likewise the Kittlitz's Plover chased the Fawn Coloured Lark from the bare shorelines near the lake and into the grasslands. While feeding, the Kittlitz's Plover backed-off or moved away from any encounters (five observations) with the larger Ringed Plover *Charadrius hiaticula*. The Ringed Plover body length is 115-130 mm compared to Kittlitz's Plover's 94-111 mm.

### 5.4.2 Resident foraging population

A total of 134 Kittlitz's Plovers were found foraging in small groups of 5-15 birds in Lake Nakuru (46 birds) and Lake Elmentaita (88 birds). Amongst these resident birds, 75 focal individuals were selected and their feeding activities assessed and documented.

Daily weather conditions were generally similar during the study period in Lake Nakuru and Lake Elmentaita. Most observation-days (78%) were sunny and hot but there were occasional cloudy and windy days. Kittlitz's Plovers sheltered themselves against strong winds or rain storm by hiding behind clumps of grass or woody debris. The plovers moved at different times of the day in small flocks from one part of the lakeshore to another. However the birds foraging on the mudflats bordering the southern and western shores of Lakes Elmenteita and Nakuru respectively were more sedentary than those occupying the other parts of the shoreline (Figure 5.1).

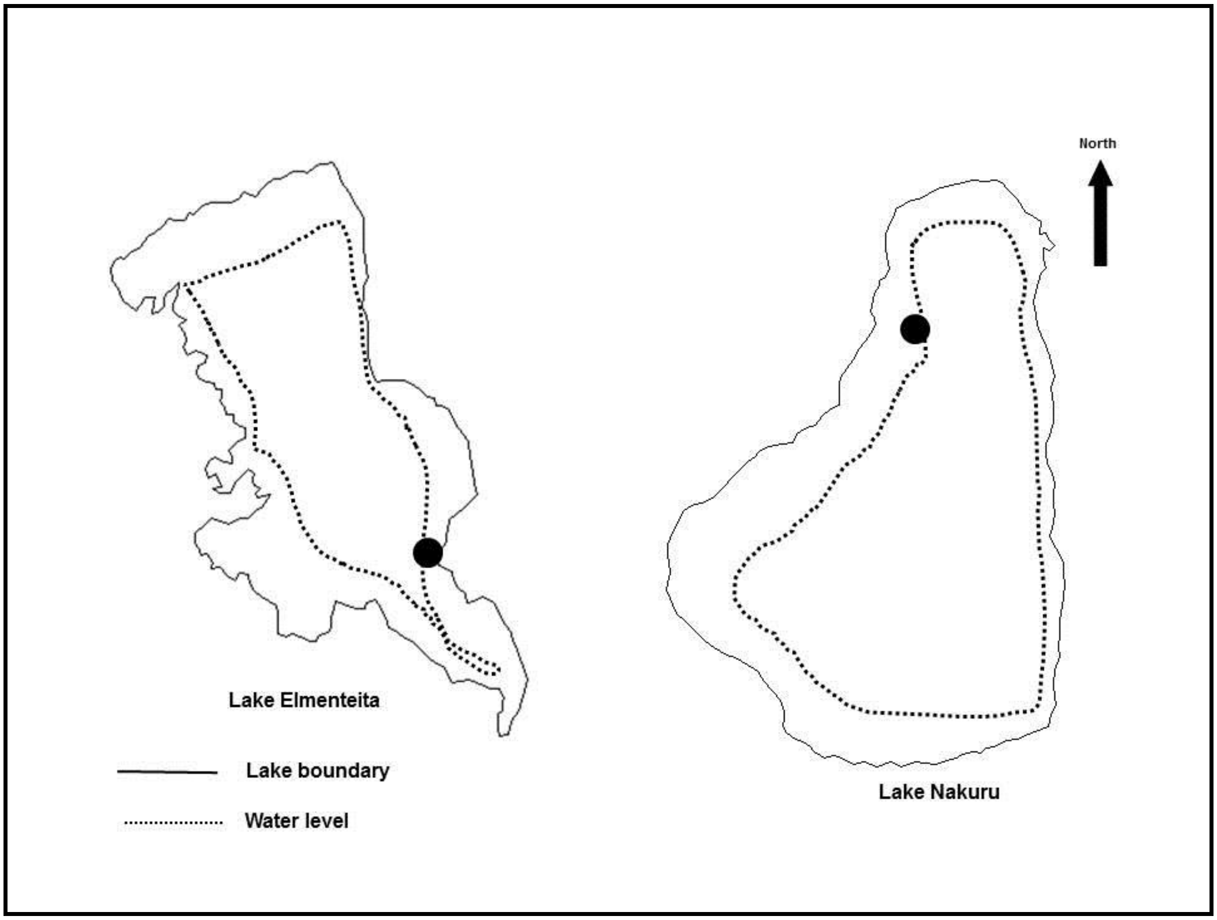



**Figure 5.1 Location of sites (solid dots) where data on foraging activities of the Kittlitz's Plover were collected in Lakes Nakuru and Elmenteita.**

Small flocks of Kittlitz's Plover were found on the same locations for several weeks during the study. The sites occupied by Kittlitz's Plover for extended period were sheltered and had minimal fluctuations in water level.

### 5.4.3 Foraging activities of the Kittlitz's Plover

A total of 126 foraging observations (63 at each study site) were collected in the months of September 2005 (Table 5.1). The birds displayed active visual feeding behaviour. This included an initial upright vigilant posture, followed by a short run, quick stop and rapid pecks at recognized prey item. A successful peck was followed by beak and head jacking forward actions that indicated swallowing of food items. This behaviour was routinely noted during feeding where a bird would pose, observe movement of its prey, then run and catch the prey.

Most of the identifiable prey items caught by the plovers were small beetles and their larvae (Coleoptera) as well as adult flies and their larvae (Diptera). The success of the food searching event and pecks at a particular site was determined by either observing the presence of the prey on the beak and the swallowing action.

**Table 5.1 Kittlitz's Plover foraging effort, efficiency and food intake rates at Lakes Nakuru and Elmenteita.**

| Site | Foraging parameter | n | median | mean | SD |
|---|---|---|---|---|---|
| Lake Elmenteita | Effort | 63 | 32.0 | 30.95 | 9.36 |
| | Efficiency | 63 | 9.0 | 9.24 | 4.11 |
| | Intake rate | 63 | 4.0 | 4.70 | 2.41 |
| Lake Nakuru | Effort | 63 | 36.0 | 34.83 | 9.74 |
| | Efficiency | 63 | 7.0 | 7.24 | 4.11 |
| | Intake rate | 63 | 3.0 | 3.70 | 2.41 |
| Total | Effort | 126 | 34.0 | 32.89 | 9.71 |
| | Efficiency | 126 | 8.0 | 8.24 | 4.22 |
| | Intake rate | 126 | 4.0 | 4.20 | 2.45 |

Kittlitz's Plovers foraged at lakes Nakuru and Elmenteita in generally similar habitats dominated by mud flats. The foraging effort (number of steps) per individual was significantly higher at Lake Nakuru than in Lake Elmenteita (Mann-

Whitney: U = 1373.5, n = 63, $P$ = 0.003). In contrast, the foraging efficiency (Mann-Whitney U = 1381.5, n = 63, $P$ = 0.003) and food intake rate (Mann-Whitney U = 1506.5, n = 63, $P$ = 0.019) were significantly higher at Lake Elmenteita as compared to Lake Nakuru. This indicates that the birds at Lake Elmenteita on average took fewer steps before reaching and pecking at prey and had more pecks that resulted in capturing and swallowing prey per unit time. This implies that the birds at Lake Elmenteita occupied a better habitat in terms of food availability or less time is devoted on vigilance or both, hence their foraging success rate was higher compared to those at Lake Nakuru.

## 5.5 Discussion

Like other shorebirds inhabiting Kenya's Rift Valley Lakes, Kittlitz's Plovers have adapted to foraging on highly variable and ephemeral food supplies. Their dialy movements seem to respond to spatial and perhaps temporal variability in food resources as well as competition pressure from other shorebirds. This study found that Lakes Nakuru and Elmenteita support small resident populations of Kittlitz's Plovers. The plovers moved considerably along the shores of the lakes but were sedentary in suitable sites with rich food and without concentrations of larger shorebirds. They avoided areas occupied by groups of Flamingos, Pelicans, Ibises, African Spoonbills and other larger shorebirds. This study also emulate that inter-specific competition especially with th Ringed Plover and larks (Red-capped and Fawn Coloured) influences their foraging behaviour and selection on feeding areas.

The results show that the birds at Lake Elmenteita on average took fewer steps before reaching and pecking at prey and had more pecks that resulted in capturing and swallowing prey per unit time. Overall this infers that the birds at Lake Elmenteita had higher food availability, spent less energy feeding and hence the foraging success rate was higher compared to Lake Nakuru.

An alternative argument is that the difference in the intake rates between the two sites could be a result of human disturbance. Lake Nakuru had a higher number of visitors compared to Lake Elmenteita. Hence, the low intake rate may be related to time lost in vigilance rather than lower food availability. The time devoted to vigilance by the Piping Plover *Charadrius melodus* in New Jersey in the United States of America as opposed to foraging was found to be directly related to the number of people near them and to the overall human use of the habitat (Burger, 1994).

Studies on Ringed Plover (which is slightly larger in size to Kittlitz's Plover) foraging on worms on a mudflat in East Anglia, United Kingdom recorded feeding effort (number of steps) ranging between 27.7 to 31.5 and intake rates (number of swallows) ranging between 0.07 to 0.23 (Liley, 1999). In this study, the effort is within the same range, but the intake rate is much higher at 4.20. The difference could be resulting from the type of items being captured. In this study, the items being taken were flying and crawling Diptera and Coleoptera in relatively drier substrates. Worms on the other hand would be obscured in the mud, hence, needing a bit more time to spot and sort-out. However, this difference could also be an indication of the different levels of disturbance, since the Ringed Plover were studied foraging in a beach park that was occasionally busy with human activity.

Hence, this study recommends further study on the effects of patchiness of food availability and vigilance directed to presence of people and other stimuli as correlates to foraging in Kittlitz’s Plover.

# CHAPTER 6: NESTING SUCCESS OF THE KITTLITZ'S PLOVER IN LAKES NAKURU AND ELMENTEITA


## 6.1 Abstract

Nests of ground nesting birds may fail to survive the incubation period through an array of causes that may be difficult to assess through studies on natural nests. Artificial nests were used to identify possible causes of nest failure, assess nesting success and map-out the distribution of good breeding sites for the species. A hundred and forty-five artificially made Kittlitz's Plover nests (with artificial eggs) were systematically placed in suitable breeding habitat of Kittlitz's Plover at the two (Lakes Elmenteita and Nakuru) study sites. Six causes of nest failure identified include flooding, heat, predation, trampling by herbivores, damage by vehicles and trampling by human. The most important causes of nest mortality were flooding at 52% followed by damage by vehicles at 17% and thirdly predation at 8%. Loss through flooding and damage by vehicles were the only factors that were statistically significantly different when compared between the two sites. Losses through floods were significantly higher at Lake Elmenteita, while through vehicles was significantly higher at Lake Nakuru. The distribution of the artificial nests that survived the 28-day incubation period closely matched the pattern of natural nests distribution especially for Lake Elmenteita. Using the Mayfield estimator, Lake Elmenteita had a higher nesting success rate of 43% compared to Lake Nakuru's of 37%. The overall nest survival rate for the two lakes combined was 41%. The two sites are therefore generally good for breeding by Kittlitz's Plover in Kenya.

## 6.2 Introduction

The Kittlitz's Plover prefers breeding around water bodies with wide barren shorelines of silt and sand (Tree et al., 1997). The species is known to breed at Lake Nakuru (Kutilek, 1974) and Lake Elmenteita. According to the data obtained from Lake Nakuru National Park management, Lake Nakuru attracted over 300,000 visitors in 2005 (see Chapter 8, Figure 8.13). Hence the pressure from tourists is high at the shores of Lake Nakuru compared to Lake Elmenteita where tourism is low. Most of the visitors are attracted to the shoreline areas, where they can observe and take photographs of the abundant flamingos, pelicans and other waterbirds. Hence these concern of conflict between ecotourism and the conservation of shoreline habitats. An understanding of the influence of human disturbance on breeding birds on the shore would help in the planning and spatio-temporal zoning of conservation areas as well as controlling visitor or public access to those conservation areas (Ikuta and Blumstein, 2003).

Nesting studies are common in investigations of birds to assess the production of breeding birds and to evaluate nesting habitats and the techniques of managing such habitats (Miller and Johnson, 1978). Artificial nests have been used in over 400 bird studies with an aim to assess potential factors affecting survival of natural bird nests (Lewis *et al.,* 2009). This Chapter investigated the causes of nest failure, areas where nests have the best chances of survival and estimates nesting success rates for Kittlitz's Plover at Lakes Nakuru and Elmenteita.

### 6.3 Materials and methods

### 6.3.1 Set-up of artificial nests

One hundred and forty-five dummy eggs made of plasticine (Møller, 1987) were used in this experimental study. The dummy eggs were coated with a creamy white paint and scented with Kittlitz's Plover faeces. The areas assessed as suitable breeding sites for Kittlitz's Plover were selected and coded as ELM1, ELM2, NAK1, NAK2 and NAK3 (Appendix 6 and Appendix 10). The artificial eggs/nests were then placed systematically in these areas (Figure 6.1).

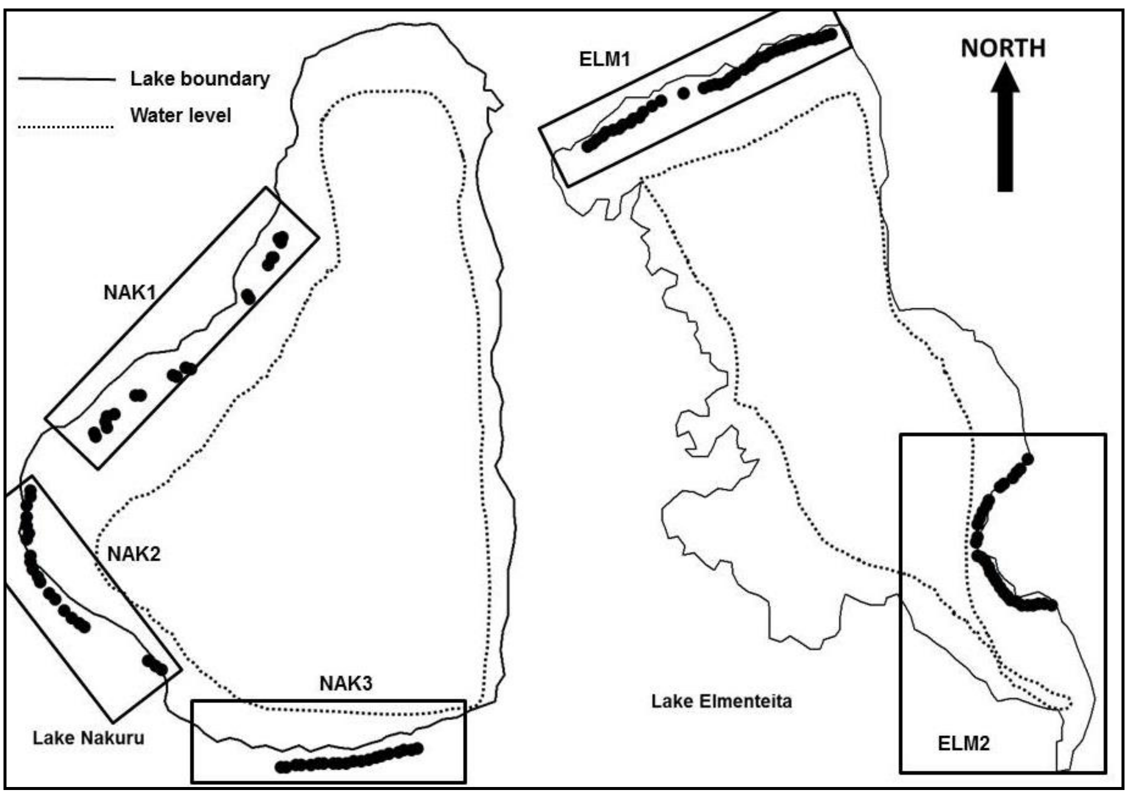



**Figure 6.1 Location of artificial nests (solid dots) and the stratification of the sites at Lake Nakuru and Lake Elmenteita.**

The eggs were made to resemble the Kittlitz's Plover eggs in size, shape, colour and weight (Hall, 1958). Egg size ranged between a length of 29.6 mm to 34.7 mm and width of 19.0 mm to 23.6 mm, and weighed between 10 g to 11 g. The dummy eggs were distributed, two each, in artificially made nest scrapes. The nests were made as a scrape using the back of the experimenter's hand. The eggs were partially covered with soil, reflecting Kittlitz's Plover behaviour when fleeing from the nest due to disturbance (Hall, 1958). A total of 61 and 84 dummy nests were placed along the shores of Lakes Nakuru and Elmenteita respectively, representing areas of known breeding occupancy by Kittlitz's Plover's individuals.

### 6.3.2 Monitoring of artificial nests

The dummy nests and eggs were then monitored for depredation every four days for a period of 28 days from 23rd August 2005. The 28 days covers the maximum incubation period for the species (Hall, 1958). During this period, data on the number of dummy eggs and the nests displaced or damaged was recorded. The eggs and areas around the nest were examined closely to identify and determine any marks left by predators and other animals that can cause damage. Rainfall data for the study period from the meteorological station was also collated. The Estimated Nest Survival and Mortality rates using the Mayfield method (Johnson, 1979; Mayfield, 1975; Farnsworth *et al.,* 2000; Aebischer, 1999; Johnson and Shaffer, 1990; Jehle *et al.,* 2004) were used to compare the nesting success between the different sections of the two lakes.

The Daily Mortality Rate (DMR), Daily Survival Rate (DSR) and Estimated Nesting Survival (ENS) were calculated as follows:

$$DMR = \frac{\text{Number of failed nest}}{\text{Total number of nests x incubation period}}$$

$$DSR = 1 - DMR$$

$$ENS = DSR^{\text{incubation period}}$$

$$ENS\% = ENS \times 100$$

## 6.4 Results

### 6.4.1 Survival rates of artificial nests

Out of the total number of dummy eggs deployed at each study site, 46% (28/61) nests had failed at Lake Nakuru compared to 16% (13/84) at Lake Elmenteita after the first three days (Table 6.1). After 28 days, only 3% (2/61) of nests survived depredation at Lake Nakuru compared to 18% (15/84) at Lake Elmenteita.

**Table 6.1 Dummy nest survival after three days and twenty-eight days of exposure**

| Site | Status | Number of nests (percentage of total) after three days | after 28 days |
|---|---|---|---|
| Lake Nakuru | Surviving | 33 (54.1%) | 2 (3.3%) |
| | Failed | 28 (45.9%) | 59 (96.7%) |
| Lake Elmenteita | Surviving | 71 (84.5%) | 15 (17.9%) |
| | Failed | 13 (15.5%) | 69 (82.1%) |
| Total | Surviving | 104 (71.7%) | 17 (11.7%) |
| | Failed | 41 (28.3%) | 128 (88.3%) |

The percentage survival of nests was higher at Lake Elmenteita than at Lake Nakuru. Survival of the artificial nests in Lake Nakuru sharply declined after the first week and progressively diminished up to the third week. Only artificial nests in section NAK2 survived beyond the third week (Figure 6.2 and Figure 6.3).

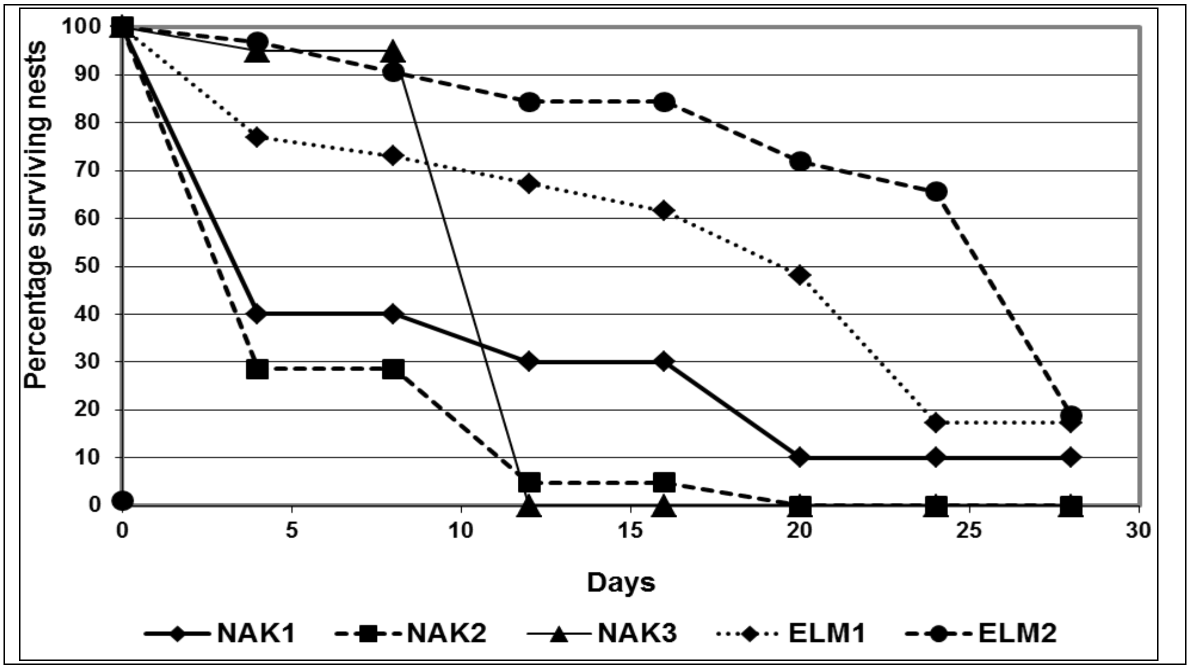



**Figure 6.2 Percentage survival of dummy nests for sections in Lakes Nakuru and Elmenteita.**

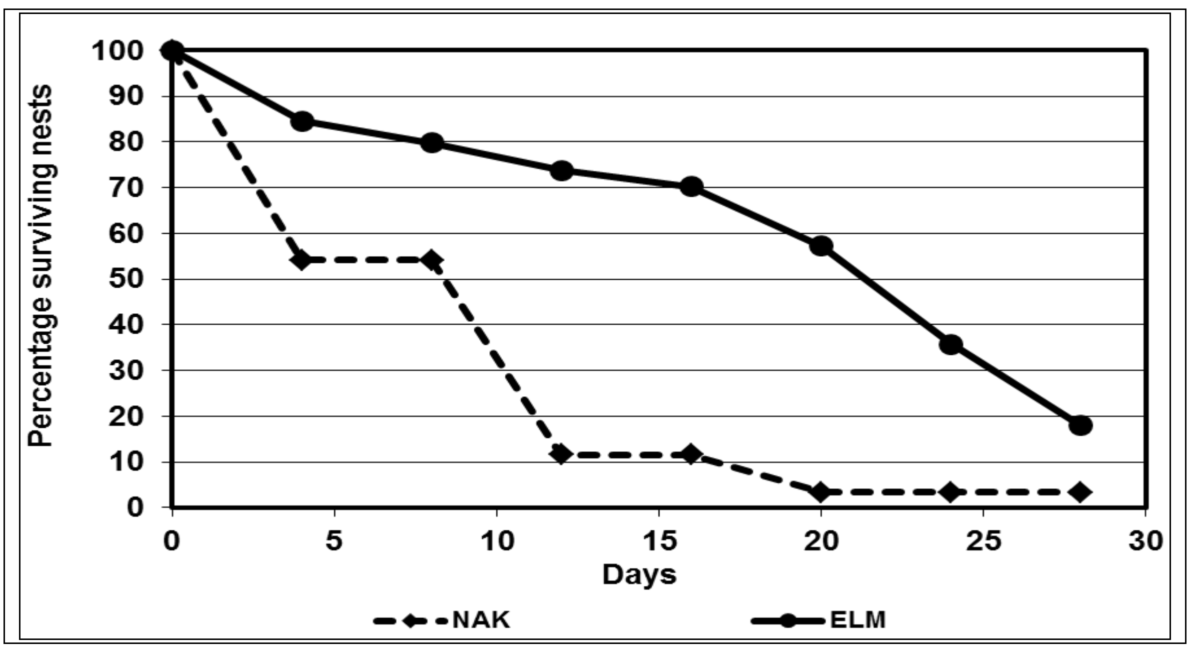



**Figure 6.3 Percentage survival of dummy nests in Lakes Nakuru and Elmenteita.**

The distribution of the nests that survived the incubation period (28 days) was the same as the distribution of natural nests at Lake Elmenteita (Figure 6.4 and Figure 6.5). The failure of the artificial nests was generally higher in Lake Nakuru that in Lake Elmenteita. Nest failure worsened with the advancing incubation period.

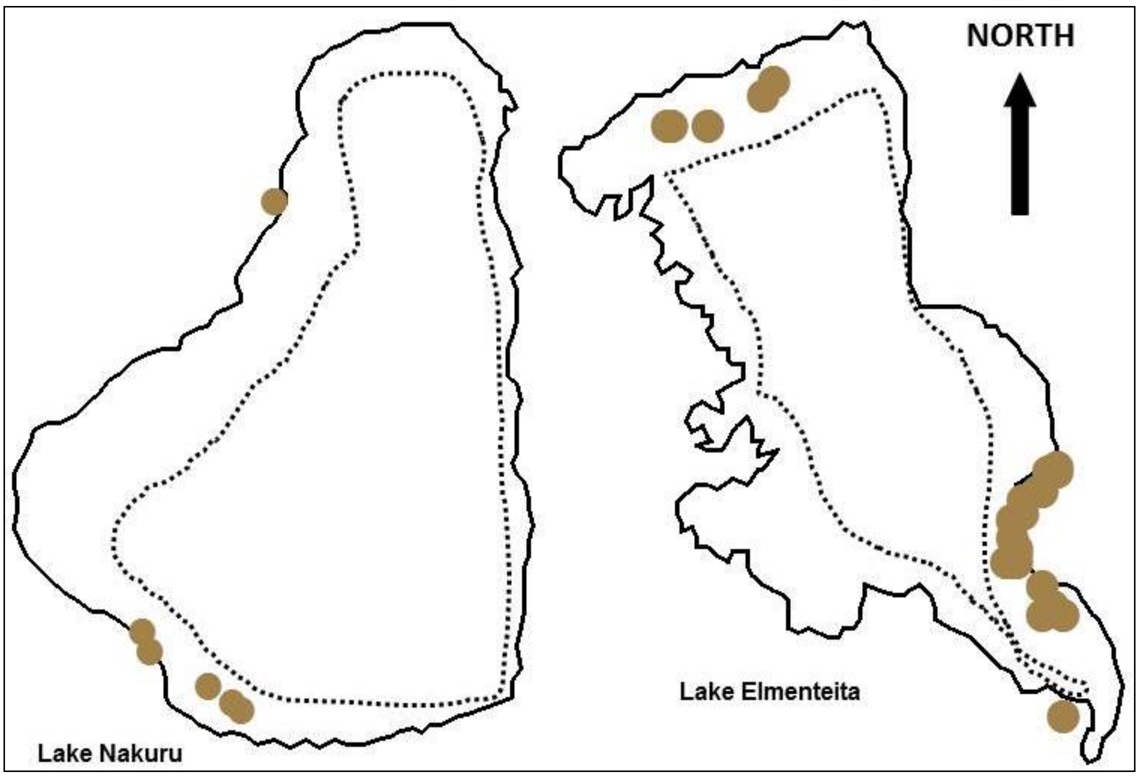



**Figure 6.4 Location of natural nests of Kittlitz's Plover (solid dots) at Lakes Nakuru and Elmenteita in between March 2005 and August 2006.**

Each dot represents one nest. The nests were predominantly found in sheltered southern shoreline of Lake Nakuru and the eastern shoreline of Lake Elmenteita.

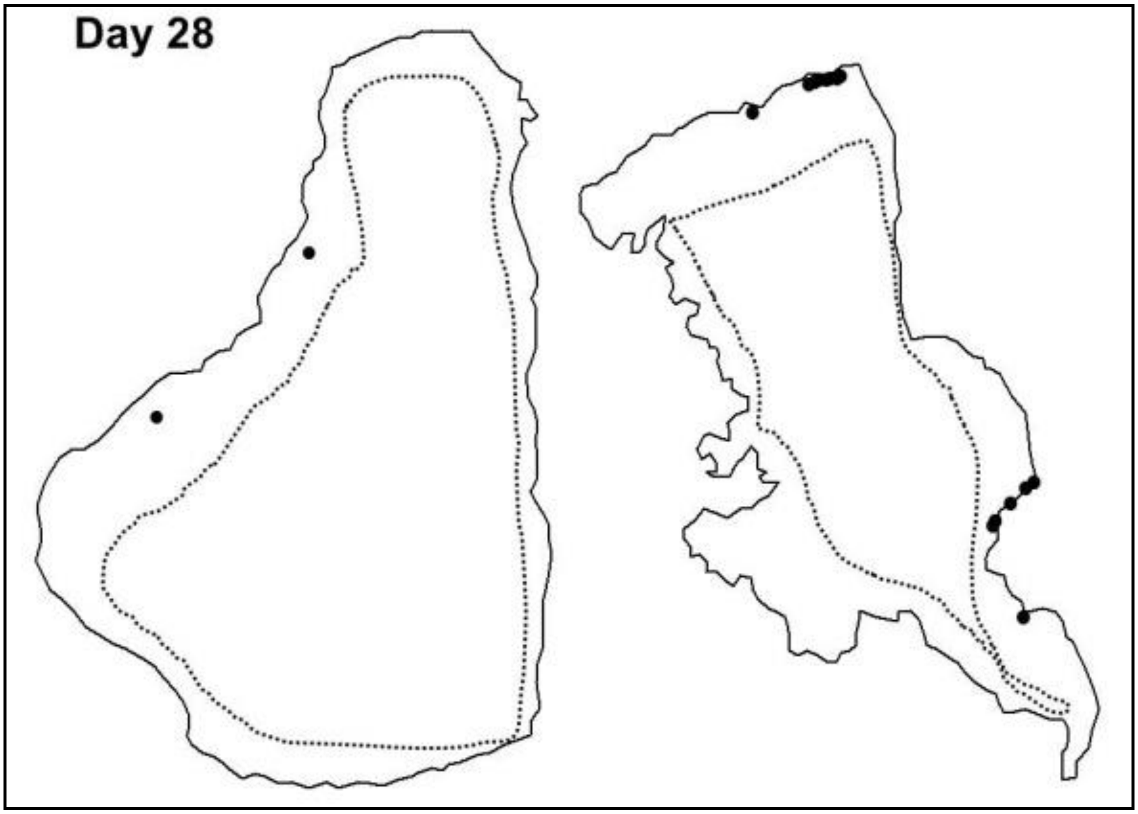



**Figure 6.5 Location of artificial Kittlitz's Plover nests (solid dots) that survived the 28-day incubation period at Lakes Nakuru and Elmenteita.**

### 6.4.2 Causes of loss of the artificial nests

The major cause of loss of dummy nests recorded was flooding with 52% (76/145) cases overall. Of these Lake Nakuru had 39% (24/61) loses compared to 62% (52/84) at Lake Elmenteita (Table 6.2). The second cause was damage by vehicle at 17% (24/145) overall, with 36% (22/61) cases at Lake Nakuru compared to 2% (2/84) at Lake Elmenteita. Predation took the third place at 8% (12/145) overall with 12% (7/61) at Lake Nakuru compared to 6% (5/84) at Lake Elmenteita. Trampling by herbivores were fourth at 7% (10/145) with 8% (5/61) at

Lake Nakuru while at Lake Elmenteita it was mainly pastoralist cattle at 6% (5/84). No failure of nest was caused by wild herbivores at Lake Elmenteita.

**Table 6.2 Factors causing loss of Kittlitz's Plover nests at Lakes Elmenteita and Nakuru.**

| Cause of nest loss | Number of nests damaged at | | |
|---|---|---|---|
| | Lake Elmenteita | Lake Nakuru | Total |
| Flood | 52 | 24 | 76 |
| Missing | 4 | 0 | 4 |
| Heat[1] | 0 | 1 | 1 |
| Predation | 5 | 7 | 12 |
| **Survived** | **15** | **2** | **17** |
| Trampled by Herbivores[2] | 5 | 5 | 10 |
| Trampled by Human | 1 | 0 | 1 |
| Damage by Vehicle | 2 | 22 | 24 |
| **Total** | **84** | **61** | **145** |

[1]Dummy eggs found crushed-in and deformed, a result attributed to overheating.

[2]At Lake Nakuru trampling was mainly by wild herbivores (Cape Buffalo) and by Cattle at Lake Elmenteita.

Loss of artificial nests due to damage by vehicles was statistically significantly higher at Lake Nakuru compared to Lake Elmenteita ($X^2$ = 28.830, df = 1, $P$ = < 0.001). Loss due to floods was statistically significantly high at Lake Elmenteita compared to Lake Nakuru ($X^2$ = 7.162, df = 1, $P$ = 0.007). The other causes (trampled by herbivores and humans, missing, heat and predation) were not statistically significant. For the artificial eggs that were 'missing', the difference between the sites was not significant $X^2$ = 2.967, df = 1, $P$ = 0.085). When 'missing' was combined with predation, they were not significantly different $X^2$ =

0.021, df = 1, *P* = 0.886 as well. When combined missing, trampled by human and predation, there was still no significant difference $X^2$ = 0.006, df = 1, *P* = 0.937. The proportion of artificial nests that survived were significantly higher at Lake Elmenteita compared to Lake Nakuru ($X^2$ = 7.207, df =1, *P* = 0.007).

### 6.4.3 Estimating nesting success using artificial nests

Using the Mayfield method, Lake Elmenteita had a higher Estimated Nesting Success (ENS) at 43% compared to Lake Nakuru at 37% (Table 6.3). The overall nest survival rate for the two lakes combined was 41%.

**Table 6.3 Estimated Nesting Success (ENS), Daily Mortality Rate (DMR) and Daily Survival Rate (DSR) of artificial Kittlitz's Plover nests at Lakes Elmenteita and Nakuru using the Mayfield method.**

| Site/Section | n | Failed | Flooded | Human | Survived | DMR | DSR | ENS | ENS% |
|---|---|---|---|---|---|---|---|---|---|
| Lake Elmenteita | | | | | | | | | |
| ELM1 | 52 | 43 | 29 | 0 | 9 | 0.030 | 0.970 | 0.432 | 43.2 |
| ELM2 | 32 | 26 | 15 | 7 | 6 | 0.029 | 0.971 | 0.438 | 43.8 |
| Lake Nakuru | | | | | | | | | |
| NAK1 | 20 | 18 | 7 | 6 | 2 | 0.032 | 0.968 | 0.401 | 40.1 |
| NAK2 | 21 | 21 | 15 | 0 | 0 | 0.036 | 0.964 | 0.361 | 36.1 |
| NAK3 | 20 | 20 | 3 | 14 | 0 | 0.036 | 0.964 | 0.361 | 36.1 |
| Total | | | | | | | | | |
| Elmenteita | 84 | 69 | 44 | 7 | 15 | 0.029 | 0.971 | 0.434 | 43.4 |
| Nakuru | 61 | 59 | 25 | 20 | 2 | 0.035 | 0.965 | 0.374 | 37.4 |
| **Total** | **145** | **128** | **69** | **27** | **17** | **0.032** | **0.968** | **0.408** | **40.8** |

Daily mortality rate was low ranging from 0.029 to 0.030, with a mean of 0.029 for both sites in Lake Elmenteita. In Lake Nakuru, the daily mortality rate was higher than at Lake Elmenteita ranging from 0.032 to 0.036, with a mean of 0.035.

### 6.5 Discussion

The study revealed six causes of nest failure: flooding, heat, predation, trampling by large herbivores and damage by vehicles and humans. Some artificial eggs were found 'missing', which could be as a result of animal activity, but may also have been removed by humans (especially at Lake Elmenteita in the areas accessible to the local community). Of these causes, the most important were flooding and damage by vehicles. The artificial nests at Lake Elmenteita were the most affected by floods. Floods that caused nest failure mainly resulted from rain that fell directly over the lakes and their environs.

Direct rainfall on the lake and environs could raise the water level around Kittlitz's Plover nesting sites, temporally for up to three centimetres, during and several hours after the rains had stopped. This water would flow in rain-made small furrows that end-up drained across the nest site destroying nests. Observations on natural nests that were likely to undergo such experiences were placed sheltered by twigs and (herbivore/cattle) dung leading to their reduced mortality. This was quite difficult to simulate with artificial nests. Also with natural nests, it is known that birds could move their eggs to the rim of the nest during rain then back after the water subsides (Kutilek, 1974).

Vehicles were the second most important factor, but it was only significant at Lake Nakuru. The results agree with previous estimates on natural nests that these are the main factors of nest mortality, even though these estimates of survival are much lower (41%) than those earlier reported. Natural nests studied in Lake Nakuru in the area estimated to coincide with NAK1 estimated 19% survival rate (Kutilek, 1974). This study estimates a survival rate of 10% (2/20) for artificial nests in NAK1 at Lake Nakuru. The difference could be as a result of the birds having better acuity in placement of their nests and the ability to protect the nests and eggs hence reducing the impact of flooding and predation.

One of the artificial nests was destroyed by extreme heat. The two artificial eggs in it were found disfigured, softened and with cracks. Heat could affect hatching success of ground nesting birds when temperature regulation of clutches by parental incubation or shading is not effective (Yasué and Dearden, 2006). This observation implies the importance of parental care in relation to ground substrate characteristics and heat absorption. The heat absorbed by the substrate on a sunny hot day may affect the eggs. Parents incubating eggs can cool the eggs by shading or belly-soaking (i.e. wetting their ventral feathers) during incubation on a hot day, thereby increasing nest survival (Amat and Masero 2007).

Another important and interesting finding was that the artificial nests that survived depict a similar pattern of distribution as the placement of natural nests. This suggests that breeding sites are quite limited for the species and that all successful sites were often fully occupied. Hence there is potential intraspecific competition for breeding sites in Kittlitz's Plover in Lakes Nakuru and Elmenteita.

The nests found in the south western section of Lake Nakuru (NAK2) had constant visits or presence of herds of Cape Buffalo (*Syncerus caffer*). The soil there was more clayey (i.e. not sandy as in the other areas). Maybe the mineral content of the soil or silt in this area influences nest success. Anecdotal observations of some natural nests in this area had more protection as the plovers used the Buffalo dung and twigs to protect the nests from getting flooded. However, they faced the risk of trampling by buffaloes.

This study has identified and prioritised the major causes of nest mortality of the Kittlitz's Plover at Lakes Nakuru and Elmenteita as well as produced indices (Appendix 10) to guide in monitoring. It has also identified areas where Kittlitz's Plover nests have better chances of survival. These findings provide a better platform for future research on how to improve conditions for ground nesting birds at these two wetlands of international importance.

# CHAPTER 7: BREEDING ECOLOGY OF KITTLITZ'S PLOVER IN LAKES NAKURU AND ELMENTEITA

## 7.1 Abstract

The breeding ecology and reproduction of Kittlitz's Plover was assessed and mapped at Lakes Elmenteita and Nakuru in 2005 and 2006, through estimation of number of nests, eggs and chicks per site per year. A total of 32 nests, 58 eggs and 66 chicks were located in total at the two sites. No significant difference was found in the characteristics of sites selected for nest placement, size of nest and number of eggs per nest between the two sites. Breeding occurred at Lake Elmenteita in both years, but did not occur at Lake Nakuru in 2006. There was no significant difference in the number of nests built, eggs laid and chicks hatched between Lake Nakuru and Lake Elmenteita in 2005. The overall number of chicks produced for the two years in the two lakes combined was 66 chicks with Lake Elmenteita contributing significantly higher percentage at 72.7% (48/66) compared to Lake Nakuru at 27.3% (18/66). Breeding occurrence across the years in Lake Elmenteita was found to be relatively more consistent compared to Lake Nakuru.

## 7.2 Introduction

Generally Kittlitz's Plovers are known to be monogamous, breeding and laying their eggs throughout the year with peak seasons varying regionally (Cramp and Simmons, 1983; Johnsgard, 1981). They typically lay two eggs which are incubated by both parents. Eggs hatch in an average of about 25 days. Precocial young, hatched wet, leave the nest as soon as they are dry. Soon after hatching parents lead their young to a feeding site (Cramp and Simmons, 1983; Johnsgard, 1981). At Lakes Nakuru and Elmenteita, this would mainly be on the mudflats on the waters' edge. The young stay near their parents, with fledging taking place in about 25 days. If threatened, parents typically perform a "broken wing display", common in *Charadrius* species to distract predators from young. After fledgling the young are independent (Cramp and Simmons, 1983; Johnsgard, 1981).

The Kittlitz's Plover has been known to breed at Lake Nakuru (Kutilek, 1974) and Lake Elmenteita. However the preference and distribution of its breeding sites around these two lakes have not been documented. This Chapter investigated the breeding ecology of Kittlitz's Plover in Lakes Nakuru and Elmenteita so as to establish factors influencing nest placement and breeding success along the shores of these two lakes.

## 7.3 Materials and methods

### 7.3.1 Searching for incubating birds, active nests, eggs and chicks

Systematic searches and scans of the study area were carried out to record breeding activities such as location of nests, pullus, juveniles and incubating birds. Searches were made at intervals of 200 m along the lakeshore. Nests were located by watching particular types of behaviour characteristic of incubating birds and parents with young (Kutilek, 1974).

Once a nest was located, the following data were recorded: (1) GPS position of nest; (2) description of general area where nest is situated (i.e. any nearby vegetation, micro-topography, nature of soil and other materials; (3) with the nest as the centre, a 1x1 meter quadrat was placed and the percentage vegetation cover estimated, substrate characteristics (silt, sand, mud, pebbles, stones and any other materials) within the quadrat were visually estimated; (4) lining material used in the nest; (5) when the nest was approached, the distance at which the bird left the nest; (6) behaviour displayed before, during and after the bird left the nest; (7) number of eggs; (8) number of chicks; (9). weight of eggs or chicks; (10) length of eggs; (11) width of eggs. Chicks that were assessed to be more than a week old were captured and ringed. The time taken for the adults to resume attending to nest or chick was also estimated.

Where active nests (i.e. with eggs) or flightless young were found, funnel traps were used to capture adults by placing the tape over the nest or the flightless young (Liley and Sutherland, 2007; McCulloch, 1991; Székely *et al.,* 2008).

These lured the adults into the trap and were captured. Hand-nets were used to pursue flightless young and capture them. All captured individuals were ringed and biometric data recorded.

**Figure 7.1 Kittlitz's Plover nest with one of the eggs covered by soil and the other exposed at Lake Elmenteita.** (Photo taken in July 2007).

### 7.3.2 Predation incidences

The only directly observed predation case during the study was of a chick that was picked by a Lanner Falcon *Falco biarmicus* on the south-eastern shoreline of Lake Elmenteita on 18$^{th}$ May 2005. An incident was also noted where a Marabou

Stork *Leptoptilos crumeniferus* approached an incubating bird. The bird stood, covered the eggs with sand and ran away from the nest performing the broken-wing act and managed to confuse and lure the Marabou Stork away from the nest hence avoiding predation. Footprints of suspected Pied Crow *Corvus albus* and carnivore (probably Silver-backed Jackal *Canis mesomelas*) were also observed on two incidents where natural nests were predated (i.e. egg shells found at nest) on the southern shoreline of Lake Elmenteita. Here Yellow-billed Stork *Mycteria ibis*, Black Kite *Milvus migrans* and feral dogs *Canis lupus familiaris* were also seen predating on Kittlitz's Plover chicks (Gichuki *pers communication*, 2006). At Lake Nakuru, two independent incidents were recorded where Pied Crow chased after adult Kittlitz's Plovers without any success.

## 7.4 Results

### 7.4.1 Nests and chicks

A total of 32 nests were located in the two sites with 26 at Lake Elmenteita and only six at Lake Nakuru during the period March 2005 to July 2006 (Appendix 9). Examining the dates when the nests and chicks were encountered showed that there was a breeding or batch cluster in terms of seasons or months between March and September (Figure 7.2).

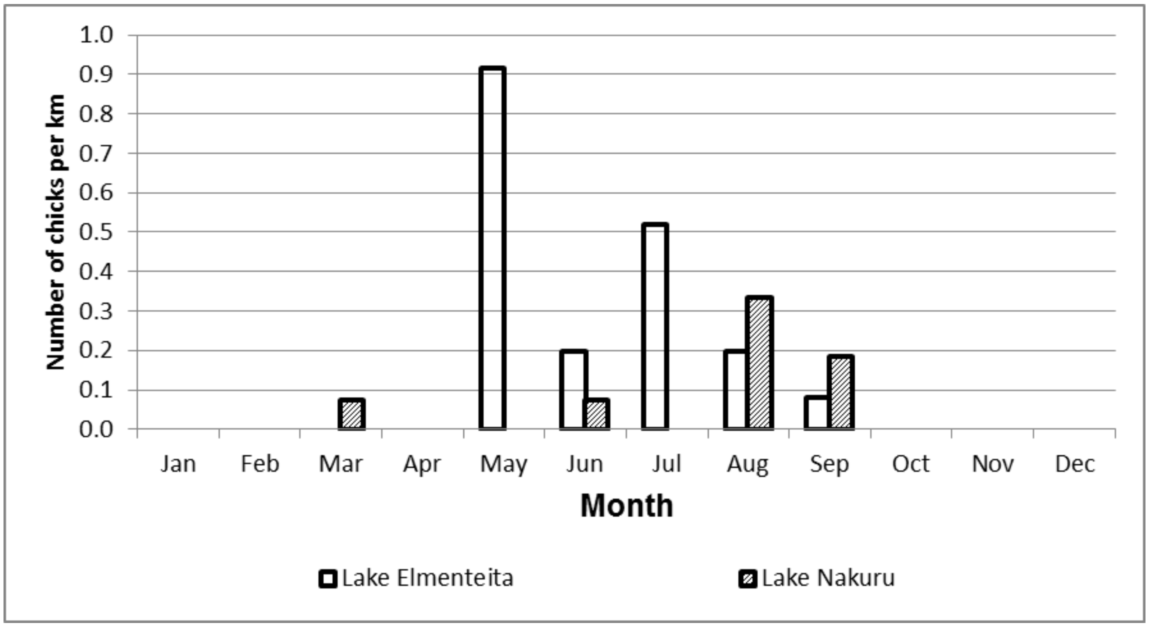



**Figure 7.2 Density of Kittlitz's Plover chicks at Lakes Nakuru and Elmenteita measured in 2005 and 2006. (**Density expressed as number per kilometre of shoreline).

### 7.4.1 Breeding seasons

Breeding activity started in March and ended in September. The peak breeding activity was in May at Lake Elmenteita and in August at Lake Nakuru. No breeding activity was noted in January and February, though past records indicated that Kittlitz's Plover also breed during these months. Breeding activity of Kittlitz's Plover was generally low in Lake Nakuru.

### 7.4.2 The characteristics and placement of Kittlitz's Plover nests

The characteristics and biometrics of the nests are summarised in (Table 7.1).

**Table 7.1 Characteristics and biometrics data of Kittlitz's Plover nests at Lakes Elmenteita and Nakuru in 2005 to 2006.** (At Lake Elmenteita n = 26 and Lake Nakuru n = 6).

| Nest parameters | mean | minimum | maximum | SD |
|---|---|---|---|---|
| **Lake Elmenteita** | | | | |
| Diameter of nest | 118.23 | 90.00 | 143.00 | 12.01 |
| Number of Eggs per nest | 1.81 | 1.00 | 2.00 | 0.40 |
| Time for adult to return to nest (sec) | 350.19 | 10.00 | 1200.00 | 342.73 |
| Distance of nest from shoreline (m) | 159.62 | 20.00 | 1000.00 | 208.43 |
| **Lake Nakuru** | | | | |
| Diameter of nest | 116.50 | 102.00 | 127.00 | 8.36 |
| Number of Eggs per nest | 1.83 | 1.00 | 2.00 | 0.41 |
| Time for adult to return to nest (sec) | 286.67 | 20.00 | 950.00 | 347.89 |
| Distance of nest from shoreline (m) | 108.33 | 40.00 | 200.00 | 55.29 |
| **Total** | | | | |
| Diameter of nest | 117.91 | 90.00 | 143.00 | 11.32 |
| Number of Eggs per nest | 1.81 | 1.00 | 2.00 | 0.40 |
| Time for adult to return to nest (sec) | 338.28 | 10.00 | 1200.00 | 347.89 |
| Distance of nest from shoreline (m) | 150.00 | 20.00 | 1000.00 | 189.58 |

The measurements are averages for the sites where the units are Diameter (mm), Time (seconds) and distance (m). The nests were in areas devoid of vegetation cover and placed at mean (±SD) distance of 150 ± 189 m from the shoreline (Figure 7.3).

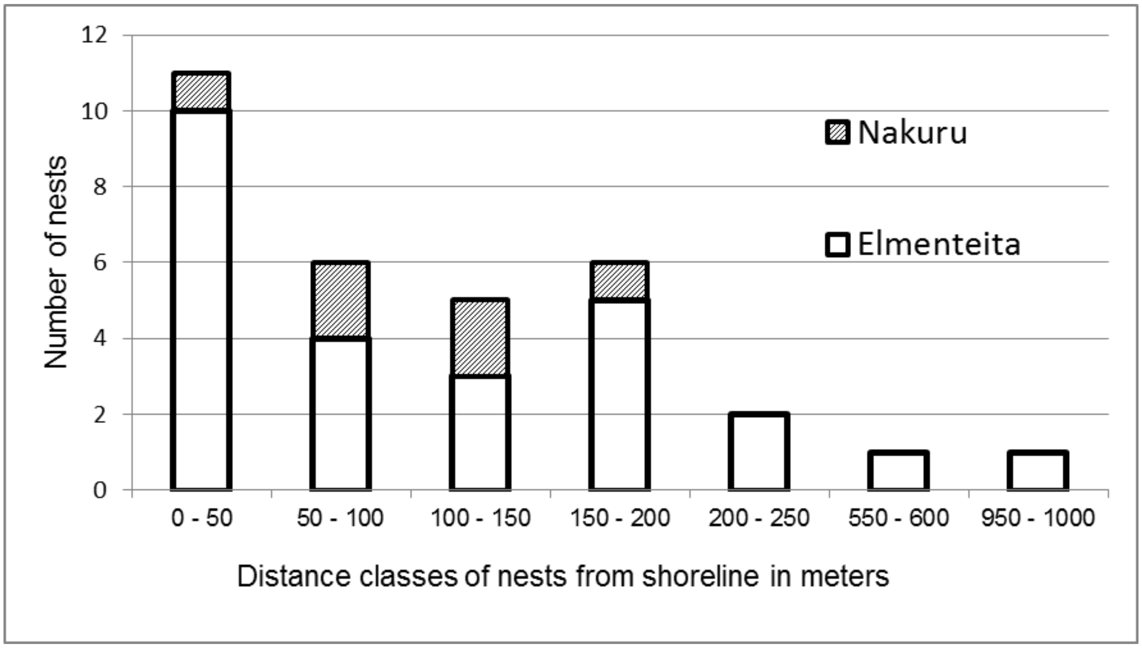



**Figure 7.3 Number of nests and distance classes from shoreline at Lakes Nakuru and Elmenteita.** (The distance classes are measured in meters).

Eighty-eight percent (28/32) of all the nests found were less than 200m distance from the shoreline of the two lakes. Generally the shore was wider thereby offering greater range of distances for nest placement from water edge at Lake Elmenteita compared to Lake Nakuru.

### 7.4.3 The characteristics and biometrics of Kittlitz's Plover eggs

The number of eggs per nest ranged from one to two. The egg biometrics are summarised below (Table 7.2).

**Table 7.2 Biometrics of eggs at Lakes Nakuru and Elmenteita.** (Lengths and width are in mm and weight in grams).

| Site | Egg biometrics | n | mean± SD |
|---|---|---|---|
| Lake Elmenteita | Length | 47 | 31.04 ± 1.17 |
| | Width | 47 | 21.96 ± 0.59 |
| | Weight | 47 | 7.55 ± 0.62 |
| Lake Nakuru | Length | 11 | 31.05 ± 1.62 |
| | Width | 11 | 21.53 ± 0.57 |
| | Weight | 11 | 7.59 ± 0.73 |
| Total | Length | 58 | 31.04 ± 1.25 |
| | Width | 58 | 21.88 ± 0.61 |
| | Weight | 58 | 7.56 ± 0.63 |

Comparisons showed no significant difference in the number of eggs laid per nest $X^2$ = 0.021, df = 1, $P$ = 0.885) between the two sites. The mean biometric length of the eggs was not significantly different ($F_{1, 56}$ = 0.001, $P$ = 0.970). The width of the eggs at Lake Elmenteita were significantly bigger ($F_{1, 56}$ = 4.797, $P$ = 0.033) than those at Lake Nakuru.

### 7.4.4 Seasonality and distribution of nests and young Kittlitz's Plover

Young birds were encountered in both sites throughout the year except in December 2005, indicating breeding activity running throughout the year with an exception of December. However all flightless chicks were captured between May and September months of 2005 and 2006 apart from two that were caught in March 2006 at Lake Nakuru. The distribution of nests and chicks are shown below (Figure 7.4 and Figure 7.5).

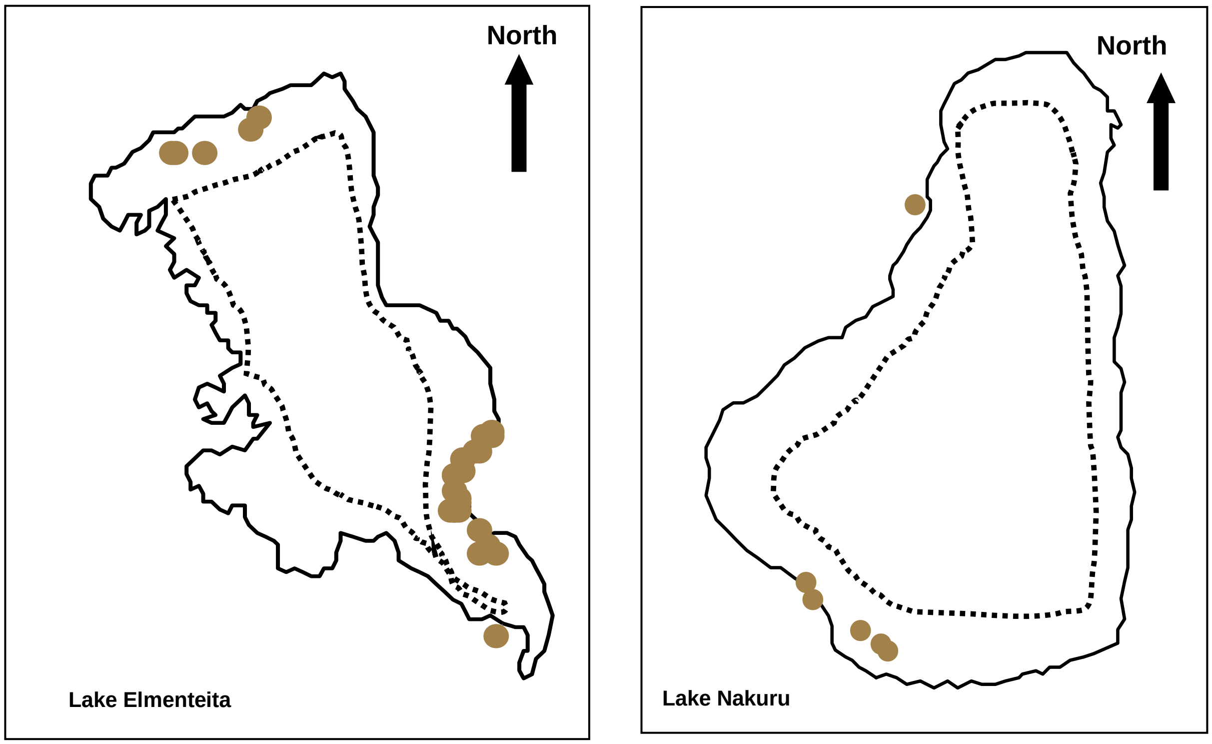



**Figure 7.4 Location of Kittlitz's Plover nests (solid dots) in relation to water level at Lakes Nakuru and Elmenteita in 2005 and 2006.**

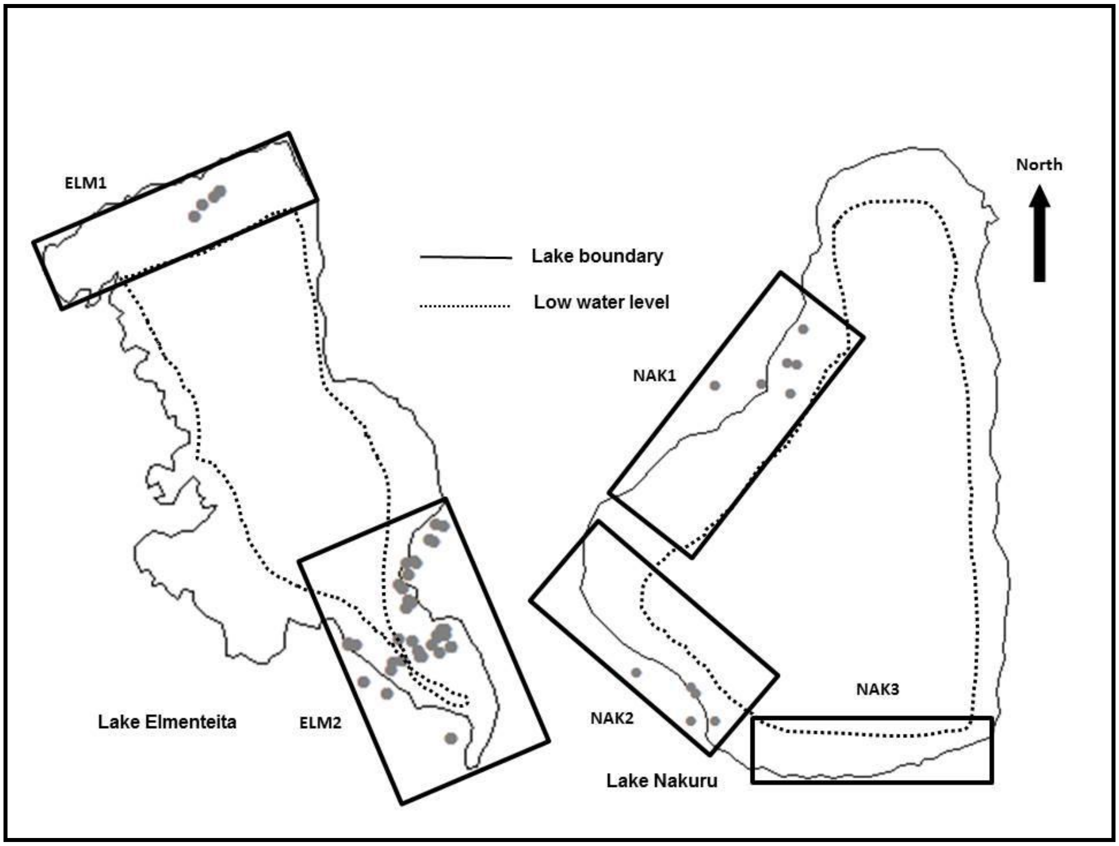



**Figure 7.5 Location of capture points for Kittlitz's Plover chicks (solid dots) at Lakes Nakuru and Elmenteita in 2005 and 2006.**

The shorelines are clustered into five areas (ELM1, ELM2, NAK1, NAK2 and NAK3) across the two sites.

### 7.4.5 Analysis of the Kittllitz's Plover nests, eggs and chicks

The numbers of chicks captured per section in the different sites shown as clusters in Figure 7.5 are summarised as follows (Figure 7.6).

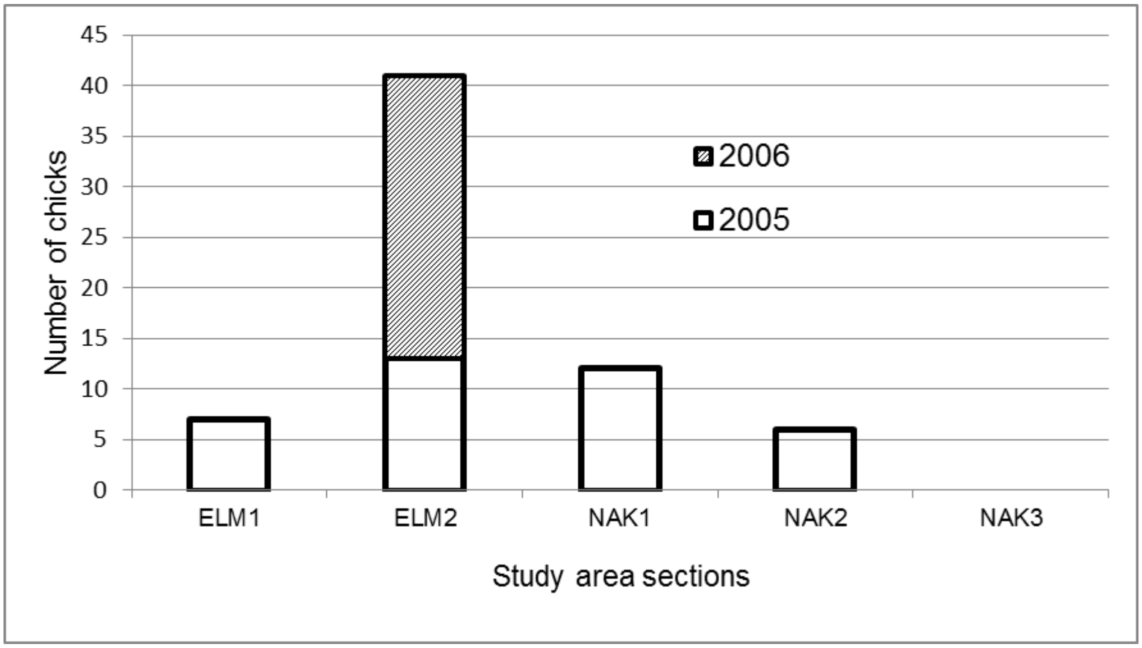



**Figure 7.6 Number of chicks in the different sections of the study areas at Lakes Nakuru (NAK) and Elmenteita (ELM) for the years 2005 and 2006.**

The density of the nests, eggs and chicks (number of individuals per kilometre of shoreline) at Lakes Nakuru and Elmenteita are summarised below (Table 7.3).

**Table 7.3 Density of nests, eggs and chicks (Number per kilometre of shoreline) at Lakes Elmenteita and Nakuru for the two years (2005 and 2006 data combined).**

| Item | Lake Elmenteita | Lake Nakuru | Total |
|---|---:|---:|---:|
| Shoreline length (km) | 25.1 | 26.9 | 52.0 |
| Nests ($km^{-1}$) | 1.04 | 0.22 | 0.62 |
| Eggs ($km^{-1}$) | 1.87 | 0.41 | 0.92 |
| Chicks ($km^{-1}$) | 1.91 | 0.67 | 1.27 |

A comparison of the density of nests, eggs and chicks between the two lakes for the two years (2005 and 2006) combined, show that Lake Elmenteita had higher densities than Lake Nakuru, but this difference was not significant ($X^2$ = 0.06, df = 2, $P$ = 0.970). The number of chicks per kilometre of shoreline was greater than the number of eggs probably due to easier detectability of chicks compared to the eggs.

Comparing the numbers at Lake Elmenteita nests 60% (9/15), eggs 59.3% (16/27) and chicks 52.6% (20/38); and Lake Nakuru (nests 40.0% (6/15), eggs 40.7% (11/27) and chicks 52.6%(18/38) were not significantly different (nests: $X^2$ = 0.6, df = 1, $P$ = 0.439; eggs: $X^2$ = 0.926, df = 1, $P$ = 0.336) in 2005. In the 2006, Lake Elmenteita had 100% nests (17/17), 100% eggs (31/31) and 100% chicks (28/28), since no breeding was recorded at Lake Nakuru in 2006.

Comparisons of these numbers between the sites for the two years combined show that Lake Elmenteita had significantly more nests 81.3% (26/32): $X^2$ = 12.500, df = 1, $P$ < 0.001; eggs 81.0% (47/58): $X^2$ = 22.345, df = 1, $P$ = < 0.001; and chicks 72.7% (48/66): $X^2$ = 13.636, df = 1, $P$ < 0.001 than at Lake Nakuru nests: 18.7% (6/32), eggs 19.0% (11/58) and chicks 27.3% (18/66).

The overall number of chicks per year for the two sites combined was 33 chicks with Lake Elmenteita having 72.7% (24/33) and Lake Nakuru having 27.3% (9/33) per year.

### 7.5 Discussion

The Kittlitz's Plover selection of breeding sites based on shoreline characteristics were similar at Lake Nakuru and Lake Elmenteita. The study shows that breeding was restricted to the northern and southern shorelines of Lake Elmenteita and western and South-western shoreline at Lake Nakuru.

The distance in the placement of the nests in relation to the shoreline identifies that human activities within 200m of the shoreline may have direct impact on the breeding and reproductive success of the species. Also generally the shore at Lake Elmenteita had comparatively more wider stretches compared to Lake Nakuru.

In 2006, breeding was recorded only at Lake Elmenteita in the southern section of the Lake and no nests and chicks were recorded at Lake Nakuru. This indicates variability from year to year in the occurrence of breeding for the species at these two sites.

This study has shown the distribution of natural nesting sites of the species and has also shown that breeding varies from year to year. The results have highlighted areas across the two sites that are potentially highly preferred by the species for breeding and consequently have higher breeding and reproductive success value. The results raise concern on the capacity of these sites to contribute to the recruitment of individuals to the larger global population. A way forward is to do more research to obtain recommendations that would increase the reproductive success of the species in the preferred areas. More research could also address how to improve conditions for breeding for the species in areas where breeding did not to occur.

The issue on how to reduce annual lapses in breeding for the species from year to year may also need to be addressed through further research. On mitigating annual lapses in breeding, the studies could focus on addressing the impact of climate (rainfall) and the use of the shoreline by human (tourism pressure and community activities) in the watershed and shorelines of the two sites. The connection between the resident breeding population of the species at these two sites with those in the immediate vicinity as well as distant sites in terms of breeding and the global population also needs to be better understood.

# CHAPTER 8 IMPACTS OF HUMAN AND ANIMAL DISTURBANCE ON BREEDING SUCCESS OF KITTLITZ'S PLOVER


## 8.1 Abstract

Disturbance can have profound influence on the foraging and breeding success of the Kittlitz's Plover. The levels of human, vehicle and animal presence as indices of disturbance to the Kittlitz's Plover were assessed on the shores of Lakes Nakuru and Elmenteita using two approaches: (1) by assessing the intensity of disturbance by counting human, vehicles and animals visiting the nesting and foraging areas of the species; (2) by documenting the frequency of footprints (of human, herbivore and predators), tyre marks and dung sampled using quadrats. The mean (± SD) number of tourist vehicles (21.7 ± 42.7) and people (6.3 ± 17.0) who came out of their cars to walk, per kilometre of shoreline per day, was higher at Lake Nakuru compared to Lake Elmenteita where no tourist vehicles were recorded during observations. The mean (± SD) number of wild mammals in the Kittlitz's Plover habitats at Lake Nakuru was estimated at 23.2 ± 58.0 per kilometre of shoreline per day. The frequency of footprints (of human, herbivore and predators), tyre marks and dung sampled using quadrats expressed in percentages revealed higher disturbance levels at Lake Nakuru by large mammals at 64.1%, people at 81.7% and vehicles at 92.9% compared to Lake Elmenteita at 35.9%, 18.3% and 7.1% respectively. Mammals at Lake Nakuru were mainly wildlife, while Lake Elmenteita had both wildlife (restricted to the northern shoreline) and (livestock restricted to the southern shoreline). Tourist inflows over time were on the increase especially at Lake Nakuru. Comparisons of disturbance parameters across the different sites reveals that

medium levels of disturbance are beneficial to the Kittlitz's Plover, while the extremes of low disturbance and high disturbance may not be beneficial. The need to restrict visitor access to Kittlitz's Plover breeding sites should be considered with caution as this may impact on any positive benefits such as reduced predation and suppression of vegetation succession.

### 8.2 Introduction

Disturbance from human recreation activities may impact vulnerable life stages of beach-nesting plovers (*Charadrius* spp.) (Ruhlen et al., 2003). Kittlitz's Plover is a common and widespread bird found in suitable habitats in Africa and Madagascar (Urban, Fry, and Keith, 1986). It prefers breeding around water bodies with wide barren shorelines (Tree *et al.,* 1997). Lakes Nakuru and Elmenteita are important sites for the conservation of waterbirds in Kenya and are listed as Ramsar sites and Important Bird Areas (Fanshawe and Bennun, 1991). They are saline and possess sections of linear and continuous shorelines that are bare, thereby attracting tourists, shorebirds and wildlife.

Lake Nakuru is a renowned tourist destination in Kenya attracting over 300,000 visitors annually. Hence the pressure from tourists is high at the shores of Lake Nakuru compared to Lake Elmenteita where tourism is low. Most tourists are attracted to its diverse wildlife and especially the huge spectacular flocks of the two species of flamingos (*Phoenicopterus ruber* and *Phoeniconias minor*) that are easily viewed from the shores of the lake. Lake Nakuru is a known breeding site for Kittlitz's Plover (Kutilek, 1974). Going by the conservation status of the two sites, Lake Nakuru with high tourism levels is an area of high human disturbance and Lake Elmenteita with limited tourism activity is an area of low human disturbance. This Chapter assesses the levels of human, wildlife and cattle as indices of disturbance on Kittlitz's Plover habitats at these two lakes.

## 8.3 Materials and methods

### 8.3.1 Sampling the numbers of humans, vehicles and herbivores

The study sites at Lake Elmenteita (ELM) and Lake Nakuru (NAK) were divided five zones. This was done based on preliminary data on the distribution of the Kittlitz's Plover numbers and nest sites as follows:-

1. ELM1 The northern section, the Ranch side
2. ELM2 The southern section, Community side
3. NAK1 the western section
4. NAK2 the south-western section
5. NAK3 the southern section

#### 8.3.1.1 Direct sampling of the numbers of humans, vehicles and herbivores

Data on human and animal density was collected from strategic viewpoints at Lake Nakuru (Baboon Cliff on the western side) and at Lake Elmenteita (cliff on the eastern side) (Figure 8.1).

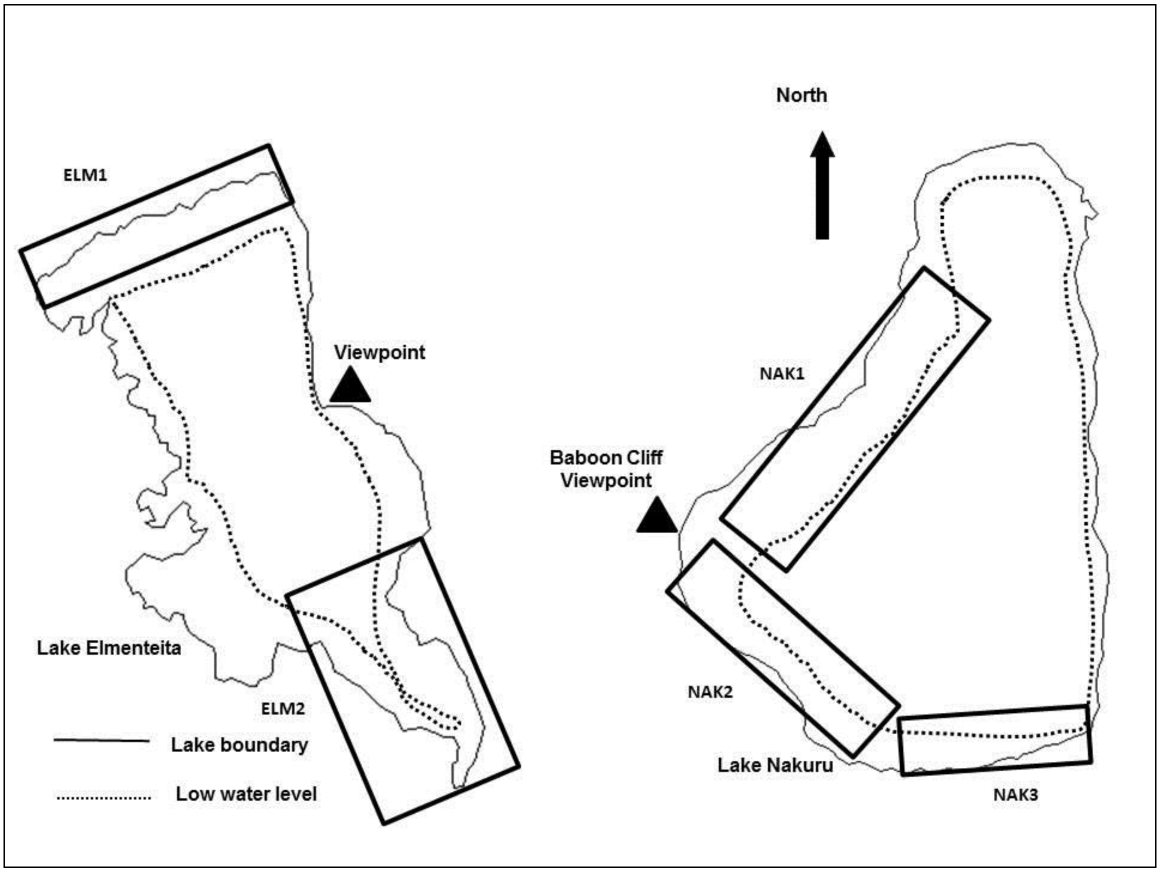



**Figure 8.1 Selected sites for disturbance assessments at Lakes Elmenteita and Nakuru.**

Equipped with telescopes, binoculars, tally counter, a sketch map, note book and pen, the observers scanned the shoreline sections of the study sites and recorded the number of vehicles, livestock, wild animals and people by section at hourly intervals from 7am to 6pm for six days per site.

#### 8.3.1.2 Indirect sampling of the numbers of humans, vehicles and herbivores

Additional data on the presence of humans, vehicles and herbivores as indices of disturbance was collected using 1x1 meter square quadrat in the different sections of the study area. Random X and Y coordinates were generated and quadrats using these coordinates were placed around the study sites. In each quadrat, the presence and absence of animal (herbivore) footprints, human footprints, predator (mammalian or bird) foot print, vehicle tyre marks, and herbivore dung were noted. Data on visitor and vehicles numbers to Lake Nakuru through the national park gate entrance were also collected to supplement direct counts at Kittlitz's Plover breeding sites.

## 8.4 Results

### 8.4.1 Number and density of human, vehicles and herbivores in Kittlitz's Plover breeding areas

Observations from the viewpoint gathered and recorded consistent flow of visitors and their vehicles to Lake Nakuru (Figure 8.2 and Figure 8.3).

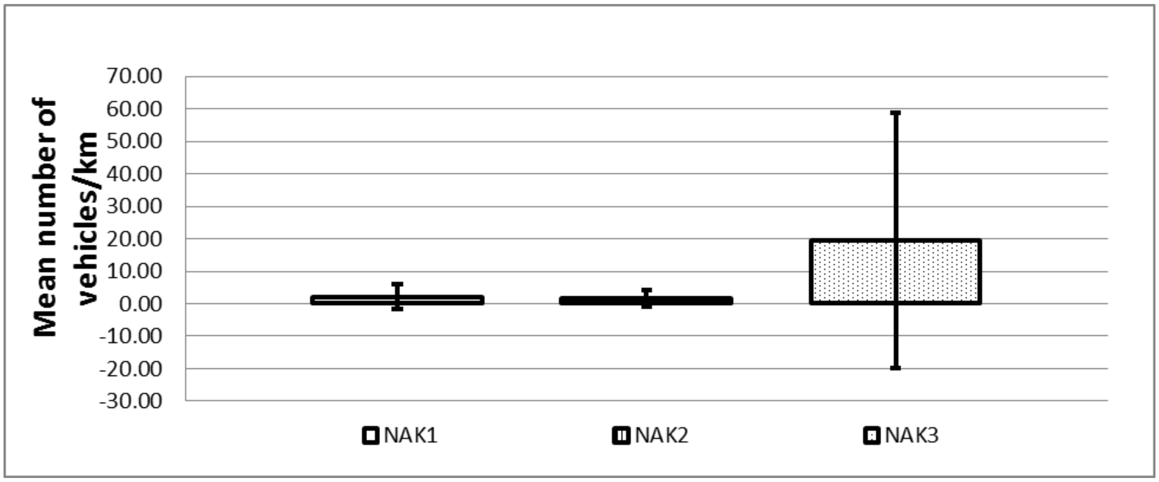



**Figure 8.2 Mean number of vehicles per kilometre per day at different sections of Lake Nakuru shoreline.** (Mean ±SD, n = 219).

The mean ±SD number of tourist vehicles was highest in Section NAK3 with about 19.5 ± 39.4 vehicle per kilometre in a day. This was followed by Section NAK1 with mean ±SD vehicle traffic at 2.1 ± 3.8 and Section NAK2 with 1.5 ±2.6 SD vehicle per kilometre in a day. Section NAK3 offered easier access to the lake shore, a drive through of 3.9 km, from one end to the other and also was nearest to the tourist lodges that are inside the lake.

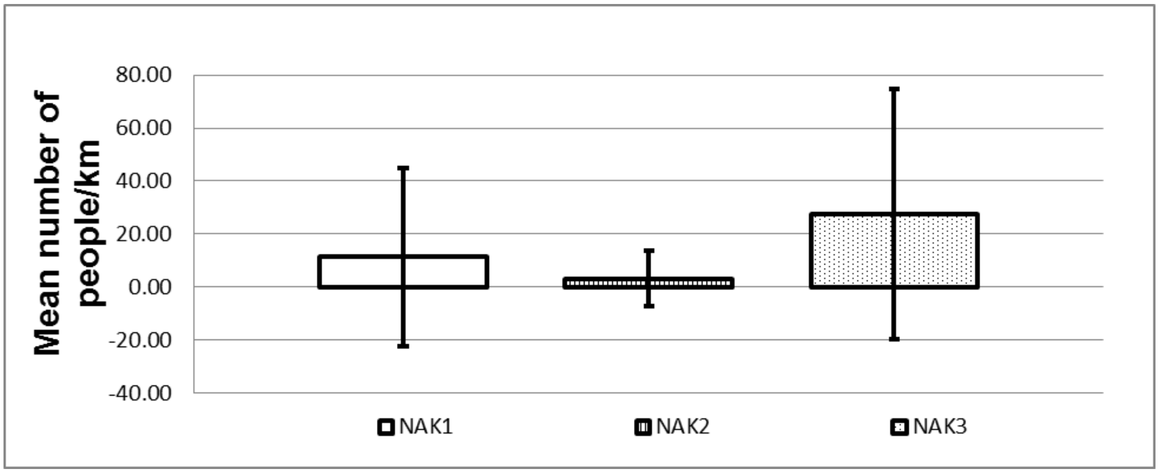



**Figure 8.3 Mean number of people counted standing or walking outside their cars per kilometre per day at different sections of Lake Nakuru shoreline.** (Mean ±SD, n = 219).

The mean (±SD) number of people who got out of their cars and walked around the shore were highest at Section NAK3 with 27.5 ± 47.3 people per kilometre of shoreline per day, followed by Section NAK1 with 11.3 ± 33.8 and Section NAK2 with 3.1 ± 10.5 people per kilometre per day.

The mean (±SD) number of herbivores at Section NAK2 was highest with 258.9 ± 247.6 herbivores per kilometre of shoreline per day, followed by Section NAK1 with 55.5 ± 202.4 and Section NAK2 with 20.9 ± 34.3 herbivores per kilometre per day (Figure 8.4).

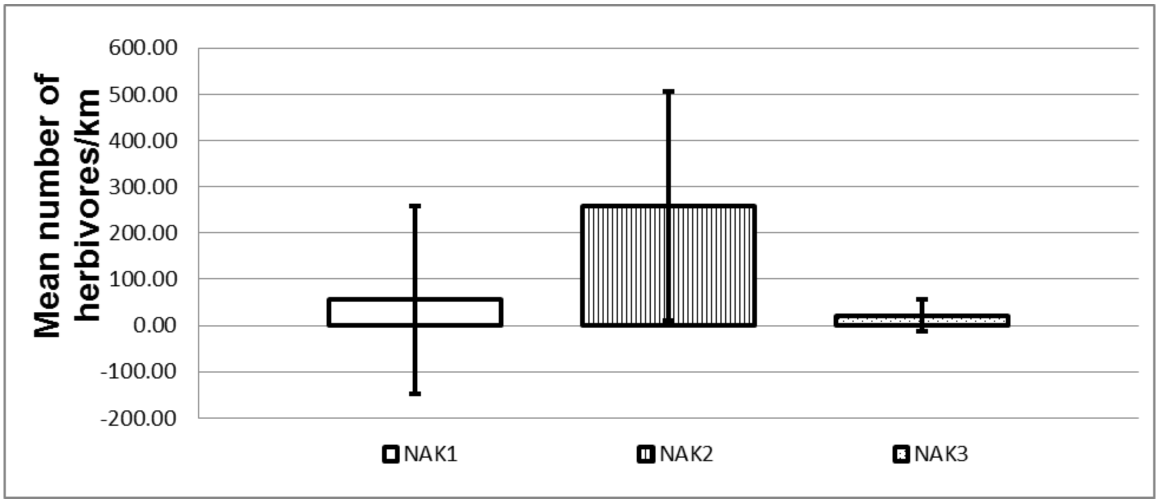



**Figure 8.4 Mean number of herbivores counted per day per kilometre of shoreline at different sections of Lake Nakuru.** (Mean ±SD, n = 219).

At Lake nakuru, there were movements of a host of wild herbivores commonly: Black Rhino (*Diceros bicornis*), White Rhino (*Ceratotherium simum*), Burchell's Zebra (*Equus burchellii*), Cape Buffalo (*Syncerus caffer*), Common Warthog (*Phacochoerus africanus*) and Deffassa Waterbuck (*Kobus ellipsiprymnus*) and Impala (*Aepyceros melampus*) encountered on all the sections (NAK1, NAK2 and NAK3) of Lake Nakuru.

**Figure 8.5 A White Rhino (*Ceratotherium simum*) with tourists on the background in Kittlitz's Plover habitat at Lake Nakuru.** (Photo taken in September 2006).

Some tourists alighted from their vehicles and walked around these sections at various points along the shore. While some of the tourists had keen interest to get closer views of the lake and the flamingos, and to take pictures. Others moved around trying to get closer to the terrestrial wildlife, mainly large mammals roaming in the proximity of the lake shore.

**Figure 8.6 Tourists and their vehicles on Kittlitz's Plover breeding habitat with flamingos on the background at Lake Nakuru shoreline.** (Photo taken in March 2006).

At Lake Elmenteita no visitor activities and other human activities were recorded from the view points during the observation days. However during the study, there were few incidences where visitors were encountered. This includes an occasion where once a bus (44-seater) full of visitors and three occasions where families in a saloon car (four to five-seater) were encountered along the southern (ELM2) section of the Lake.

**8.4.2 Analysis of the numbers and densities of human, vehicles and herbivores in Kittlitz's Plover breeding areas**

Analysis of observations in the three sites at Lake Nakuru revealed significant site differences for the numbers of vehicles ($F_{2, 654}$ = 35.997, $P$ = < 0.01) and people ($F_{2, 654}$ = 38.648, $P$ = < 0.01) that came out of their vehicles at NAK1, NAK2 and NAK3. The mean number of large herbivores ($F_{2, 654}$ = 38.785, $P$ = < 0.01) was significantly higher at NAK2 compared to the other two sections.

At Lake Elmenteita, the wild herbivores (mainly included Burchell's Zebra, Cape Buffalo, Common Warthog, Deffassa Waterbuck and Impala) were observed on the northern section (ELM1). Along the southern shores of Lake Elmenteita (ELM2), herds of livestock (mainly cattle, sheep and goats) were regularly observed in the morning and evening, moving to and from nearby community grazing areas.

Some limited collection of the commercial soda ash was observed in the southern side of Lake Elmenteita. Hence at times there would be people scrapping the ground, collecting the soda ash and stacking them into sacks. A lorry would then come once a week or fortnight to collect sacks of the product. Sometimes the sacks were collected using donkey-carts. The intensity of disturbance by vehicles, people and herbivores measured using quadrat sampling across the two sites is summarised in Table 8.1

**Table 8.1 Summary of relative intensity of disturbance by vehicles, people and herbivores measured as frequencies using quadrats expressed as percentages.**

| Factor | Lake Nakuru | Lake Elmenteita | Total |
|---|---|---|---|
| People | 81.7 | 18.3 | 100 |
| Vehicles | 92.9 | 7.1 | 100 |
| Herbivores | 64.1 | 35.9 | 100 |
| Litter (solid waste) | 0 | 100 | 100 |

Results from the quadrat sampling were analysed using Pearson's Chi-square. There was significant difference in the frequency of vehicles – tyre marks ($X^2$ = 622.832, df = 4, *P* = < 0.001) and human foot prints ($X^2$ = 74.865, df = 4, *P* = < 0.001) across all the sections (NAK1, NAK2, NAK3, ELM1 and ELM2) in the two study sites (Figure 8.7 and Figure 8.8).

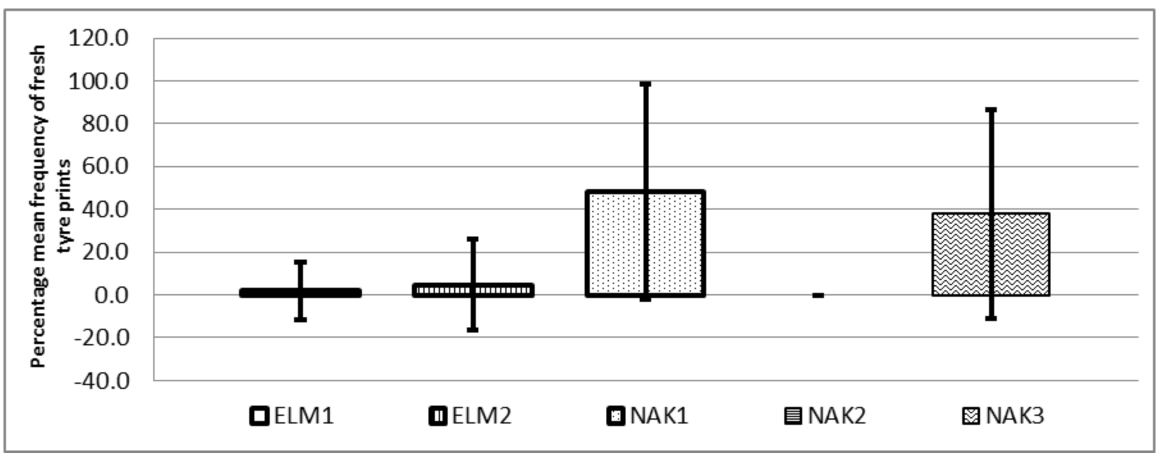



**Figure 8.7 Mean frequency of vehicle tyre prints gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

For Lake Nakuru the fresh vehicle tyre prints were highest in NAK1 followed by NAK3 and very low in Nak2. At Lake Elmenteita the fresh vehicle tyre prints were in lower frequencies at ELM1 and ELM2 compared to NAK1 and NAK3, but more than NAK2.

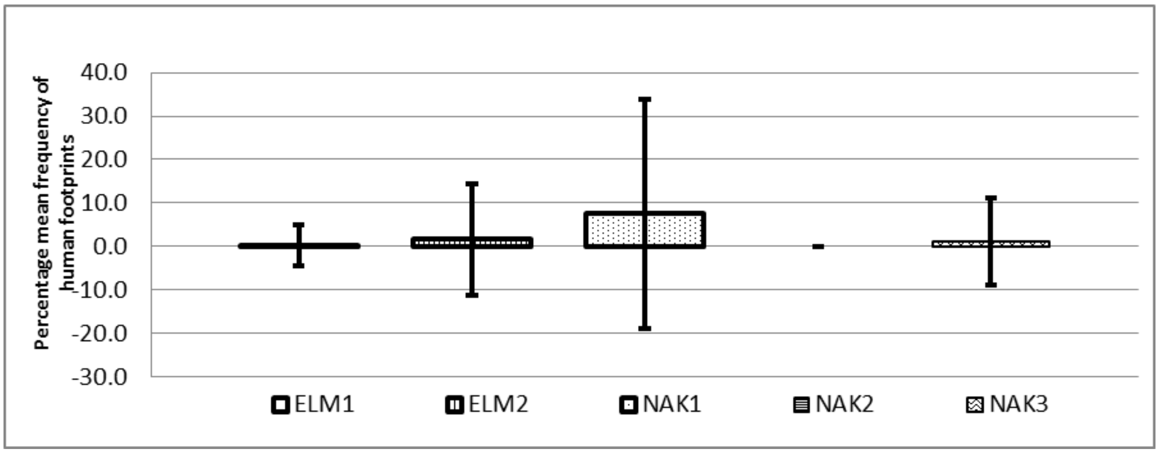



**Figure 8.8 Mean frequency of human foot prints gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

Litter (solid waste) ($X^2$ = 2.126, df = 4, $P$ = 0.713) levels were very low across all sites and showed no significant difference when compared using Pearson's Chi-square across all sections of the study sites (Figure 8.9).

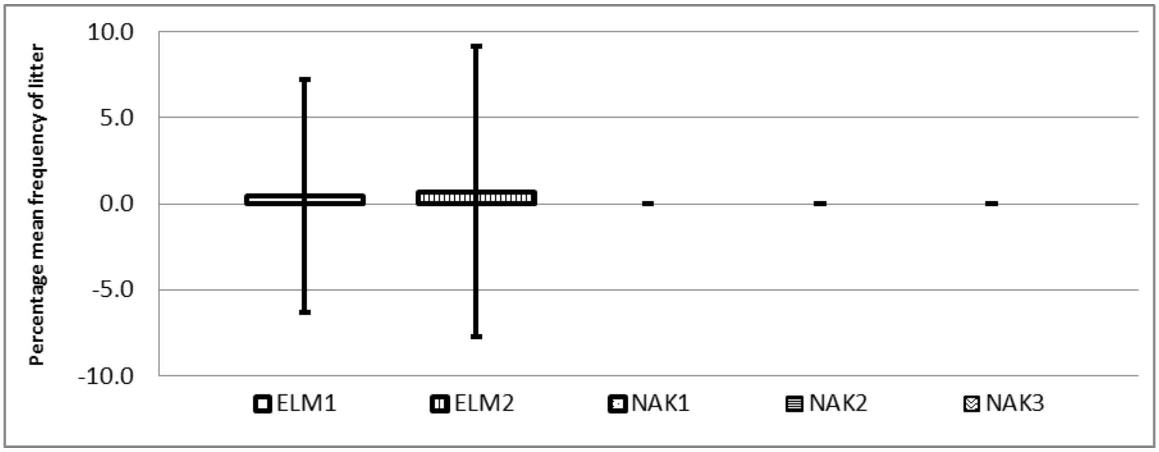



**Figure 8.9 Mean frequency of litter (solid waste) gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

The disturbance levels related to human activities were high at NAK1 possibly due to its proximity to the main gate, hence it is the nearest accessible area of the Lake for visitors entering the National Park. NAK3 on the southern shore is closest to the tourist lodges in the National Park, hence visitors accommodated in the lodges would conveniently visit this section in the morning and evening game drives. NAK2 section had limited access by road for visitors with not so clear continuous access to the other sections.

Levels of herbivores including livestock to Lake Elmenteita – herbivore foot print ($X^2$ = 138.688, df = 4, $P$ = < 0.001), dung or droppings ($X^2$ = 377.896, df = 4, $P$ = < 0.001), and mammalian and bird predator – foot prints ($X^2$ = 13.943, df = 4, $P$ = < 0.001) were significantly different across all sections in the two sites (Figure 8.10, Figure 8.11 and Figure 8.12).

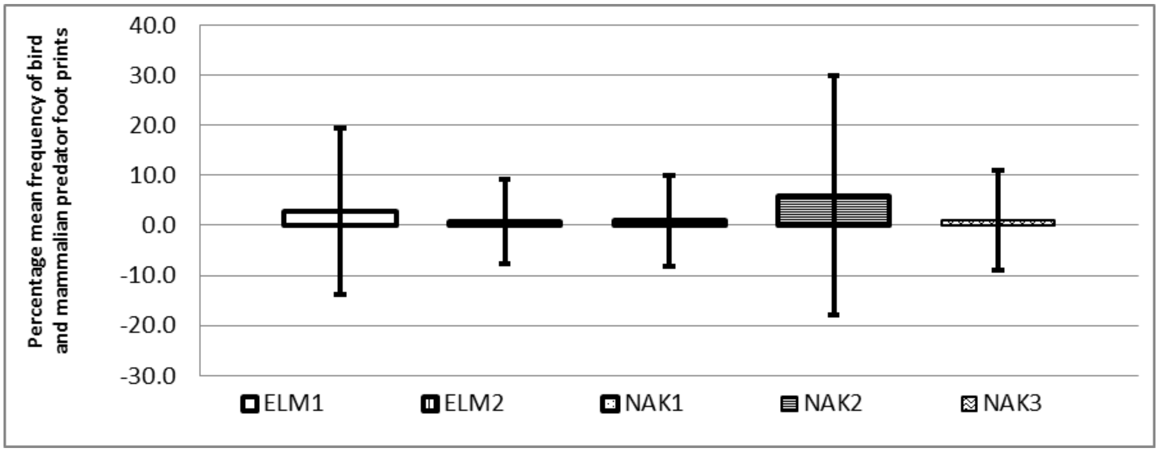



**Figure 8.10 Mean frequency of bird and mammalian predator foot prints gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

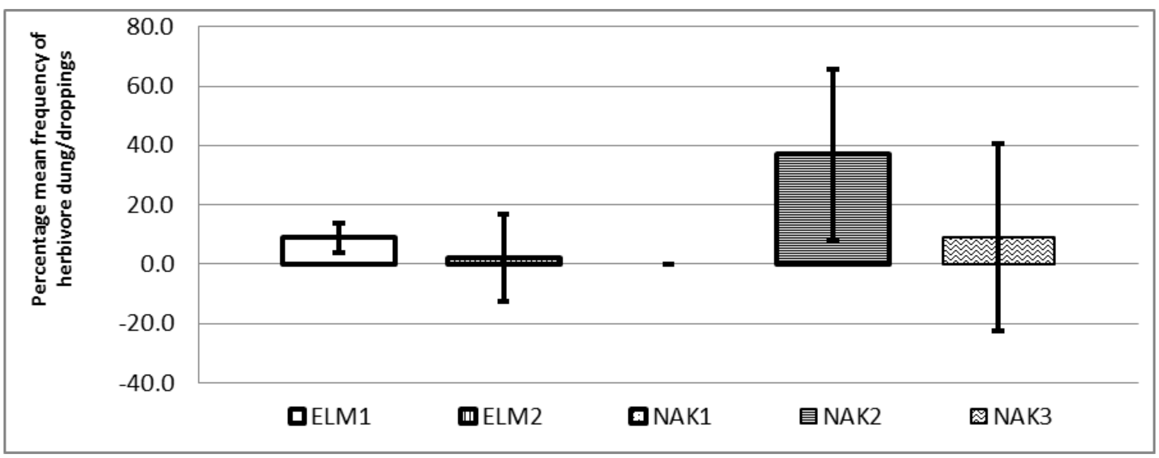



**Figure 8.11 Mean frequency of herbivore dung/droppings gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

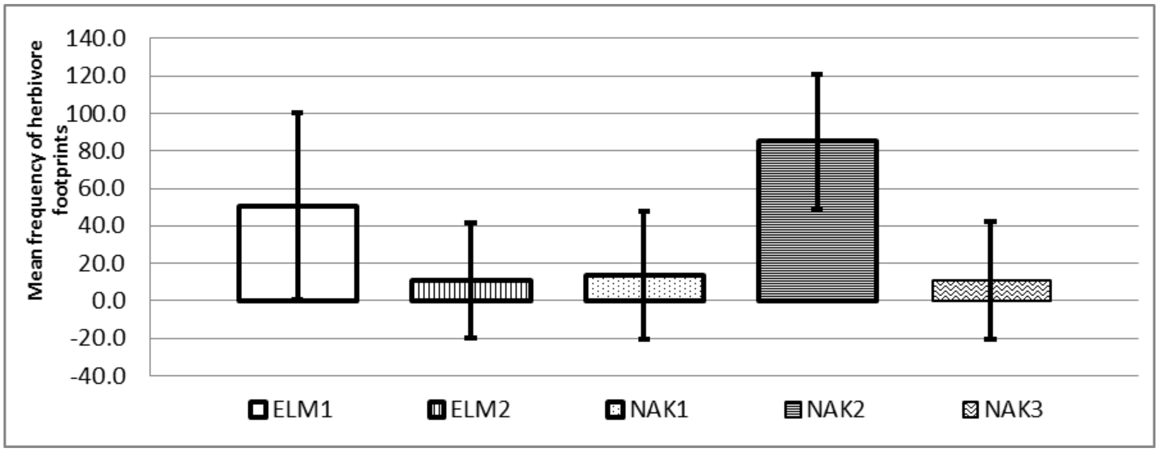



**Figure 8.12 Mean frequency of herbivore foot prints gathered using quadrat sampling at Lakes Nakuru and Elmenteita study sections.** (Mean ±SD, n = 219).

### 8.4.3 Trend of annual visitor numbers entering Lake Nakuru

The annual visitor numbers entering Lake Nakuru from 1975 to 2005 obtained from the gate records showed a consistent increasing trend over the years (Figure 8.13).

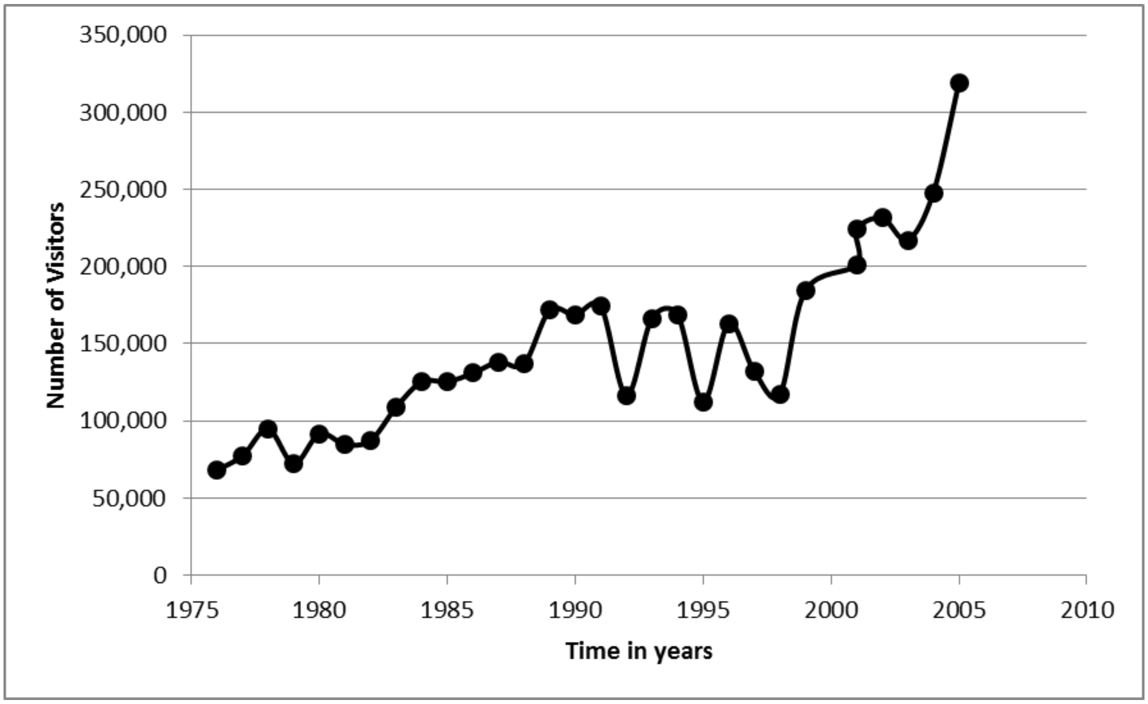



**Figure 8.13 Trend in annual numbers of visitors to Lake Nakuru from 1976 to 2005.**

The monthly visitor numbers maintain similar annual trend year after year with progressive increase in numbers (Figure 8.14).

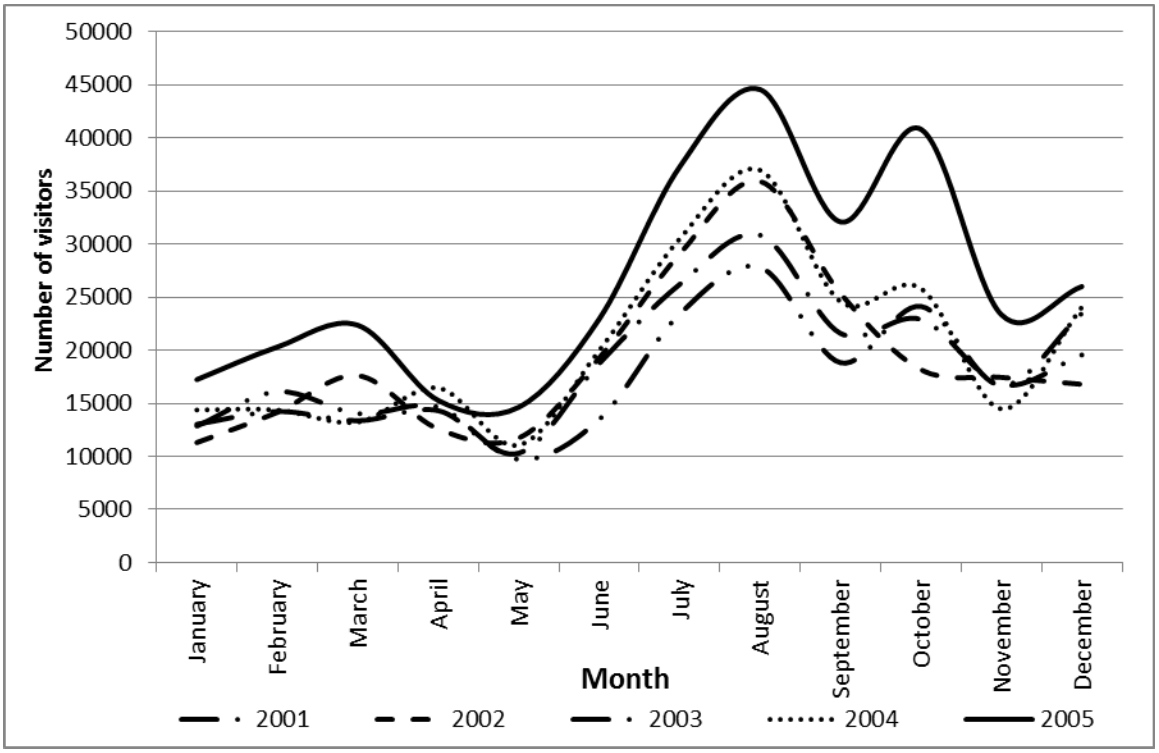



**Figure 8.14 Monthly visitor numbers at Lake Nakuru for the years 2001 to 2005.**

The visitor numbers to Lake Nakuru depict two main seasons: low season from January to May, and the high season from August to October. While the number of visitors to Lake Nakuru may be influenced by factors outside the site, rainfall patterns seem to have some local influence since the roads inside the National Park are earth roads, and hence are impassable during heavy rains.

### 8.4.4 Impact of disturbance on Kittlitz's Plover breeding and nesting success

The Mayfield values of Estimated Nesting Success in area where some artificial nests survived by section was: NAK1 40.1%, ELM1 48.3% and ELM2 40.7%

(Chapter 6). The levels of disturbance from this Chapter by section can be ranked as ELM1 (Low = 1), ELM2 (Medium =2), and NAK1 (High = 3). Hence matching these rankings with Mayfield values we find that nesting success may benefit from medium disturbance and decline with high levels of human disturbance (Figure 8.15).

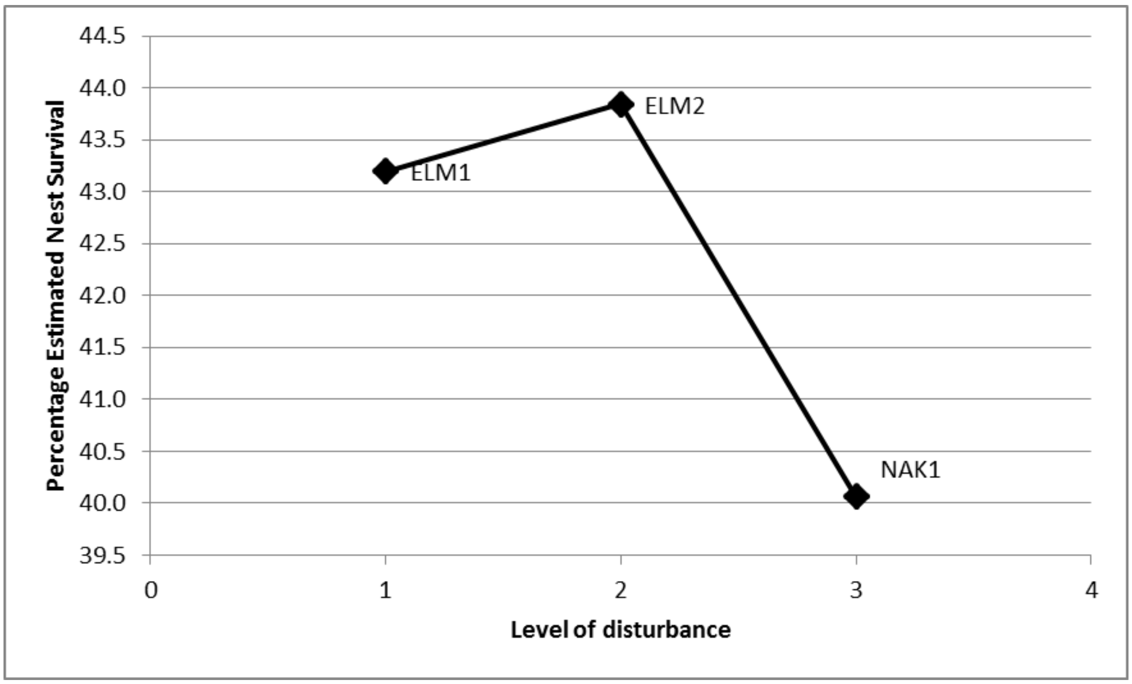



**Figure 8.15 Estimated Nest Survival against ranked levels of human disturbance.**

The relationship between Estimated Nest Survival and human disturbance indicate a trend of increase from low to medium disturbance and a decrease from low and medium to high disturbance. This could be as a result of confounding factors such floods and predation. The medium level disturbance area (open to the community) had the highest estimates of nest survival for the species.

### 8.5 Discussion

Results from direct and indirect disturbance assessments were generally similar. The highest numbers of visitors and vehicles were recorded in the western area of Lake Nakuru (NAK1) which is also the area closest to the main gate. This section also had the highest numbers of Kittlitz's Plover. Hence, disturbance had the greatest potential of disrupting Kittlitz's Plover breeding activities at the site.

Litter (solid waste) was absent at Lake Nakuru, but noted at Lake Elmenteita. This shows that the National Park rules around Lake Nakuru that control littering are effective. Some litter enter the park to the Lake area through storm water, but the management conducts some cleaning campaigns.

The levels of human disturbance were low at Lake Elmenteita as expected. The southern shore (ELM2) that was open to the community had medium level indices of human and vehicle densities. At Lake Elmenteita, litter levels were higher in the community side. On the ranch side, which is closed-off to visitors, the litter may be washed-in from the other areas of the lake accessible to the public.

Predator indices were high at the south-western shoreline of Lake Nakuru (NAK2) and the ranch (ELM1) section of the Lake Elmenteita. These two areas had also the lowest numbers of visitors and vehicles, and high numbers of herbivores (cattle in the case of Elmenteita and wildlife for Lake Nakuru) and dung. Some interpretation of this could lead to inferring that disturbance may have some positive impact of lowering predation, hence increasing survival of brood. However, logical trade-offs could be inferred here i.e. high disturbance from human, vehicles and herbivores in the area contributing to low numbers of predators, but higher mortality of brood through damage and trampling. Kittlitz's Plover tended to place their nests in proximity to herbivore dung in these areas. Trampling of nests and brood by herbivores was low to negligible as revealed in Chapter 6.

The trend of visitor numbers to Lake Nakuru over time show a continuous increase. There is likelihood that Lake Elmenteita will soon also start having increased number of visitors given the growing tourist facilities around the lake. The increase in number of visitors at Lake Nakuru who are keen to get close to the shoreline to view flamingos will continue to impact on breeding and foraging of the Kittlitz's Plover. There are two waves of visitors. A low season — that runs from December/January to April and a high season — that runs from August to October. The high season coincides with the peak breeding season for the Kittlitz's Plover. These findings present a starting point from which to look into how management of visitors could be made to improve the breeding and foraging

Kiittlitz’s Plover. However, there is caution on directly restricting public access as this may impact on any positive benefits such as reduced predation and suppression of vegetation succession. Hence, there is need to go beyond behavioural studies and explore the consequences of disturbance on the species demographic and population processes (Gill, 2007). Behavioural responses are always context-dependent and individual responses to human presence will therefore depend on the trade-offs experienced by those individuals. For example, the decision to stay or to leave an area in response to disturbance will be influenced by the quality of the area, the availability and relative quality of alternative areas, relative predation risk on current and alternative sites, and so on. Animals may remain in disturbed areas because the cost of moving to a new location is too great or because food resources are more abundant or predation risk is lower than in alternative sites (Gill, 2007).

# CHAPTER 9: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

## 9.1 Introduction

The aim of this study was to improve conservation and management of shorebirds in the Rift Valley lakes in Kenya. Towards this goal this study identified Kittlitz's Plover as the study species and Lakes Nakuru and Elmenteita as suitable study sites.

The study assessed the factors affecting the Kittlitz's Plover population size, trends and movements by specifically investigating:

1. The impact of human disturbance, water level changes and climate on movement, population size and distribution of Kittlitz's Plover at Lakes Nakuru and Elmenteita.
2. The impact of human disturbance, water level changes and climate on foraging of the Kittlitz's Plover at Lakes Nakuru and Elmenteita.
3. The impact of human disturbance, water level changes and climate on the breeding success of Kittlitz's Plover at Lakes Nakuru and Elmenteita.
4. The management implications arising from human disturbance, water level changes and climate for Kittlitz's Plover at Lakes Nakuru and Elmenteita.

This Chapter provides broader context and interrelationships among the attributes investigated by this study.

## 9.2 General discussion

### 9.2.1 Factors affecting the population size, trends and movement

This study reaffirms that Kittlitz's Plover prefers barren areas of lake shores for feeding and nesting around Lakes Nakuru and Elmenteita. The data used in this study (covering the period 1991 to 2006) suggested a population size ranging from a maximum of 668 birds to as low as 60 birds for the two sites combined. Their occurrence and abundance appears to be dependent on rainfall patterns. The itinerant characteristics of the species make them highly responsive to short-term changes within season rainfall and their numbers fluctuate considerably between wet and dry years and seasons (Lipshutz *et al.,* 2011). Lakes Nakuru and Elmenteita are shallow lakes, and intense periods of rainfall can have a huge impact on the presences of Kittlitz's Plovers as it can submerge their preferred habitats within a very short period. This short-term phenomenon has a high effect on their presence, ability to nest and movements than the average monthly water level of the lakes.

From a climate change perspective, changes in the local and regional hydrological cycle are projected to cause increased variation in the intensity, duration, and frequency of precipitation events (Mirhosseini *et al.,* 2012). In the tropics, general increases in water vapour associated with warmer climate produces increased precipitation intensity (Meehl *et al.,* 2005). Steady moderate rains (low intensity) soak into the soil and benefit plants, while the same amounts of rainfall in a short period of time (high intensity) may cause local flooding and runoff (Trenberth, 2011). This trend does not favour the long term persistence of

Kittlitz's Plovers at Lakes Nakuru and Elmenteita. Even though the two lakes are just 15 km apart, inter-lake movement (between Lakes Nakuru and Elmenteita) of the species was not established as there were no recoveries of ringed birds. However, methods and efforts of capture may have limited the recapture of ringed birds to prove inter-lake movements.

The numbers of the Kittlitz's Plover increased at Lake Elmenteita with a corresponding decrease in numbers at Lake Nakuru. Increased wetness results in increased lake levels and reduced areas of preferred habitat. This trend observed from a dry to a wet year, suggest that the species numbers decrease in Lake Nakuru with a simultaneous increase at Lake Elmenteita. Further, long term data would be needed to confirm this.

Lakes Nakuru and Elmenteita receive sporadic influx of immigrant Kittlitz's Plover especially in the months of December - January and sometimes July that may inflate the numbers of the resident population. The influxes may imply opportunistic behaviour of the species seeking suitable sites for breeding as the key driver for movement rather than foraging only. This has consequence and long term implications on the species in years when flooding and/or tourism increases in their regular breeding areas. The densities of Kittlitz's Plovers were higher in areas of medium levels of human disturbance.

### 9.2.2 Foraging behaviour in areas with different levels of disturbance

This aspect was studied on Kittlitz's Plovers feeding on mudflats at Lakes Nakuru (with high perceived human disturbance) and Elmenteita (with low perceived human disturbance). The foraging rates in the areas perceived to have low human disturbance was higher than at the areas perceived to have high human disturbance.

However, human disturbance and other confounding factors that may include predation levels and food availability cannot be ruled out. The overall conclusion however, is that birds at Lake Elmenteita spent less energy feeding and hence their foraging success rate was higher compared to those at Lake Nakuru. The study established that there were differences in foraging rates between areas of high and low human disturbance. High human and vehicle disturbance were disadvantageous to foraging Kittlitz's Plover.

### 9.2.3 Breeding success in areas with different levels of human disturbance

The numbers and distribution of nests and chicks matched areas of perceived medium human presence. However the entire Lake Nakuru (with high perceived human disturbance) cumulatively had lower numbers of nests and chicks compared to Lake Elmenteita (with low perceived human disturbance). At Lake Nakuru, the nests and chicks were found in the sections of perceived high and medium human disturbance. At Lake Elmentieta, there were more nests and chicks in the section open to the community than in the ranch section that had less perceived human disturbance. Comparisons of these sections across the two sites put the community area at Lake Elmenteita to have medium level disturbance. The study adduces that there are differences in the breeding success of Kittlitz's Plovers in relation to the levels of human disturbance and especially moderate disturbance which appears to be beneficial.

### 9.2.4 Management implications

The management implications arising from the findings of this study are:

1. Creating awareness about ground nesting shorebirds to the management and tourists of Lakes Elmenteita and Nakuru.
2. Creating awareness about ground nesting shorebirds targeted to the adjacent communities around Lake Elmenteita.
3. Zoning of areas suitable for Kittlitz's Plover breeding and foraging for management to meet the species' habitat requirements.
4. Erecting signages to restrict and control tourist activities in the breeding areas of Kittlitz's Plover around Lakes Elmenteita and Nakuru.

## 9.3 Conclusions

The conclusions of this study are:

1. Rainfall is the key climatic factor that drives and influences many aspects of the Kittlitz's Plover distribution, movement, foraging and breeding ecology at Lakes Elmenteita and Nakuru.

2. Rainfall influences several aspects of Kittlitz's Plover ecology by its seasonality and intensity influencing lake water levels, habitat extent, breeding season and success, food availability and foraging.
3. Moderate disturbance by numbers of herbivores, vehicles, people and their activities along the shores of Lakes Elmenteita and Nakuru are beneficial to Kittlitz's Plover breeding and foraging success, while the disturbance extremes (very high and very low) may have detrimental impacts.
4. The study lays solid ground on which to build future studies and the manifestation of human impacts on the long-term survival of the population of Kittlitz's Plover at Lakes Nakuru and Elmenteita.

## 9.4 Recommendations

The recommendations of this study are:

1. Develop long term study programme and monitoring of breeding shorebirds at Lakes Elmenteita and Nakuru to improve their management and shed more light on their movement patterns and ranges.
2. Control of flooding and tourist activities to improve breeding success of the Kittlitz's Plover at Lakes Elmenteita and Nakuru.
3. Develop policies on human-wildlife interactions with special interest in addressing disturbance and the plight of resident ground nesting shorebirds at Lakes Elmenteita and Nakuru.

## REFERENCES

Acreman, M. C. and Hollis, G.E. (1996). Water management and wetlands in Sub-Saharan Africa. International Union for Conservation of Nature and Natural Resources (IUCN).

Aebischer, N. J. (1999). "Multi-way comparisons and generalized linear models of nest success: extensions of the Mayfield method." *Bird Study* 46 (S1): S22–S31.

Amat, J. A. and Masero, J.A. (2007). "The Functions of Belly-Soaking in Kentish Plovers Charadrius Alexandrinus." Ibis 149 (1): 91–97.

Baldizzone, G. and van der Wolf, H.W. (2011). "On Afrotropical Coleophoridae (I) (Lepidoptera: Coleophoridae)." *SHILAP Revista de Lepidopterologia* 39 (156): 351–377.

Battin, J. (2004). "When good animals love bad habitats: ecological traps and the conservation of animal populations." *Conservation Biology* 18 (6): 1482–1491.

Beale, C. M. (2007). "The behavioral ecology of disturbance responses." *International Journal of Comparative Psychology* 20 (2).

Beale, C. M. and Monaghan, P. (2004). “Human disturbance: people as predation-free predators?” *Journal of Applied Ecology* 41 (2): 335–343.

Belsoy, J., Korir, J. and Yego, J. (2012). “Environmental Impacts of Tourism in Protected Areas.” *Journal of Environment and Earth Science* 2 (10): 64–73.

Bennun, L. A. and Njoroge, P. (1999). “Important bird areas in Kenya.” *Nature Kenya, Nairobi(Kenya). 318*: 196–211.

Bennun, L. A. and Nasirwa, O. (2000). “Trends in waterbird numbers in the southern Rift Valley of Kenya.” *Ostrich* 71 (1-2): 220–226.

Blaker, D. (1966). “Notes on the sandplovers *Charadrius* in southern Africa.” *Ostrich* 37 (95): 102.

Brower, J.E., Zar, J.H. and von Ende, C.N. (1990). Field and Laboratory Methods for General Ecology, Third Edition. Wm. C. Brown Publishers, Dubuque, IA. 237 pp.

Burger, J. (1991). “Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*).” *Journal of Coastal research*: 39–52.

Burger, J. (1994). "The effect of human disturbance on foraging behavior and habitat use in piping plover (*Charadrius melodus*)." *Estuaries* 17 (3): 695–701.

Burger, J, and Gochfeld, M. (1991). "Human activity influence and diurnal and nocturnal foraging of sanderlings (*Calidris alba*)." *Condor*: 259–265.

Collar, N. J., Crosby, M.J. and Stattersfield, A.J. (1994). *Birds to watch 2: the world list of threatened birds*: the official source for birds on the IUCN red list. BirdLife International.

Conway, W. G, and Bell, J. (1968). "Observations on the behavior of Kittlitz's Sandplovers at the New York Zoological Park." *Living Bird* 7: 57–70.

Cramp, S., Simmons, K.E.L., Brooks, D.C., Collar, N.J., Dunn, E., Gillmor, R., Hollom, P.A.D., Hudson, R., Nicholson, E.M. and Ogilvie, M.A. (1983). *Handbook of the birds of Europe, the Middle East and North Africa. The birds of the Western Palearctic: 3. Waders to gulls*.

Davenport, J. and Davenport, J.L., (2006). "The impact of tourism and personal leisure transport on coastal environments: a review." *Estuarine, Coastal and Shelf Science* 67 (1): 280–292.

David, J.L. (2009) “The macro-Lepidoptera fauna of acacia in the Kenyan Rift Valley (part 2 - description of new species).” *TROP. LEPID. RES.*, 19(1):9-17.

Delaney, S., Scott D.A., Dodman, T. and Stroud, D.A. (2009). *An atlas of wader populations in Africa and Western Eurasia*. Wetlands International Wageningen.

Delaney, S. and Scott, D.A. (2002). *Waterbird population estimates*. Wetlands International.

Dixon, A.B. and Wood, A.P. (2003). Wetland cultivation and hydrological management in eastern Africa: Matching community and hydrological needs through sustainable wetland use. In *Natural Resources Forum*, 27:117–129.

Elias, S. P, Fraser, J.D. and Buckley, P.A. (2000). “Piping plover brood foraging ecology on New York barrier islands.” *The Journal of wildlife management*: 346–354.

Fanshawe, J.H. and Bennun, L.A. (1991). “Bird conservation in Kenya: creating a national strategy.” *Bird Conservation International* 1 (03): 293–315.

Farnsworth, G. L., Weeks, K.C. and Simons, T.R. (2000). “Validating the assumptions of the Mayfield method.” *Journal of Field Ornithology* 71 (4): 658–664.

Fraser, L. H. and Keddy, P.A. (2005). *The world’s largest wetlands: ecology and conservation*. Cambridge University Press.

Frid, A, and Dill, L.M. (2002). “Human-caused disturbance stimuli as a form of predation risk.” *Conservation Ecology* 6 (1): 11.

Gichuki, N., Wakanene, K. and Gatere, G. (1997). (*unpublished*)“Biodiversity profile of Nakuru district and its environs, Kenya.” National Museum of Kenya, Research Reports.

Gill, J. A. (2007). “Approaches to measuring the effects of human disturbance on birds.” *Ibis* 149 (s1): 9–14.

Gill, J.A., Norris, K. and Sutherland, J.W. (2001). “Why behavioural responses may not reflect the population consequences of human disturbance.” *Biological Conservation* 97 (2): 265–268.

Gill, J.A., Sutherland, W.J. and Watkinson, A.R. (1996). “A method to quantify the effects of human disturbance on animal populations.” *Journal of Applied Ecology*: 786–792.

Gilroy, J.J. and Sutherland, W.J. (2007). “Beyond ecological traps: perceptual errors and undervalued resources.” *Trends in Ecology & Evolution* 22 (7): 351–356.

Gregory, R. D., Vorisek, P., Noble, D.G., van Strien, A., Klvanova, A., Eaton, M., Meyling, A.W.G., Joys, A., Foppen, R.P.B. and Burfield, I.J. (2008). “The generation and use of bird population indicators in Europe.” *Bird Conservation International* 18 (1): S223.

Hall, K.R.L. (1958). “Observations on the nesting sites and nesting behaviour of the Kittlitz’s Sandplover *Charadrius pecuarius*.” *Ostrich* 29 (3): 113–125.

Hall, K.R.L.. (1959). “Nest records and additional behaviour notes for Kittlitz's Sandplover *Charadrius pecuarius* in the SW Cape Province.” *Ostrich* 30 (1): 33–38.

Hockey, P.A.R., Dean, W.R.J. and Ryan, P. (2005). *Roberts birds of southern Africa*. Trustees of the John Voelcker Bird Book Fund.

Del Hoyo, J., Elliot A. and Sargatal, J. (1992). “Handbook of the Birds of the World. Barcelona: Lynx Editions.”

Hughes, R.H., Hughes, J.S. and Bernacsek, G.M. (1992). *A Directory of African Wetlands*. IUCN.

Ikuta, L. A. and Blumstein, D.T. (2003). “Do fences protect birds from human disturbance?” *Biological Conservation* 112 (3): 447–452.

Isaksson, D. (2009). Predation and shorebirds: predation management, habitat effects and public opinions. Department of Zoology; Zoologiska institutionen. *PhD Thesis*. University of Gothenburg, Sweden.

Jędrzejczak, M. F. (2004). “The modern tourist’s perception of the beach: Is the sandy beach a place of conflict between tourism and biodiversity?” *Coastline reports* 2: 109–119.

Jehle, G., Adams, A.A.Y., Savidge, J.A. and Skagen, S.K. (2004). “Nest survival estimation: a review of alternatives to the Mayfield estimator.” *The Condor* 106 (3): 472–484.

Johnsgard, P.A. (1981). *The plovers, sandpipers and snipes of the world*. University of Nebraska Press Lincoln.

Johnson, D.H. (1979). “Estimating nest success: the Mayfield method and an alternative.” *The Auk*: 651–661.

Johnson, D.H. and Shaffer, T.L. (1990). “Estimating nest success: when Mayfield wins.” *The Auk*: 595–600.

Johnson, M.D. (2007). “Measuring habitat quality: a review.” *The Condor* 109 (3): 489–504.

Junk, W.J. (2002). “Long-term environmental trends and the future of tropical wetlands.” *Environmental Conservation* 29 (4): 414–435.

van de Kam, J., de Goeij, P. and Moore, S.J. (2004). *Shorebirds: an illustrated behavioural ecology*. KNNV Utrecht.

Khamala, C.P. (1975). “Breeding habitats and biting activities of Culicoides (Diptera: Ceratopogonidae) at Lake Nakuru National Park, Kenya, with special reference to *C. trifasciellus* Goetghebuer.” *East African medical journal* 52 (7): 405.

Kokko, H., and Sutherland, J.W. (2001). “Ecological traps in changing environments: ecological and evolutionary consequences of a behaviourally mediated Allee effect." *Evolutionary Ecology Research* 3 (5): 537–551.

Kristan, I.W.B. (2003). "The role of habitat selection behavior in population dynamics: source-sink systems and ecological traps." *Oikos* 103 (3): 457–468.

Kutilek, M.J. (1974). "Notes on Kittlitz's sandplover and the blacksmith plover at Lake Nakuru." *African Journal of Ecology* 12 (1): 87–91.

Leichtenfried, M. and Shivoga, W. (1995). "The Njoro River-Lake Nakuru Ecotonal System in Kenya."*Jber.Biol.Stn Lunz* 15:67-77.

Lewis, R.M., Armstrong, D.P., Michael K. J., Richard, Y., Ravine, D., Asa Berggren, A. and Boulton, R.L. (2009). "Using artificial nests to predict nest survival at reintroduction sites." *New Zealand Journal of Ecology* 33 (1): 40.

Liley, D. (1999). Predicting the consequences of human disturbance, predation and sea-level rise for Ringed Plover populations. *PhD Thesis.* University of East Anglia, UK.

Liley, D. and Sutherland, W.J. (2007). “Predicting the population consequences of human disturbance for Ringed Plovers *Charadrius hiaticula*: a game theory approach.” *Ibis* 149 (s1): 82–94.

Lipshutz, S., Remisiewicz, M., Underhill, L.G. and Avni, J. (2011). “Seasonal fluctuations in population size and habitat segregation of Kittlitz’s Plover *Charadrius pecuarius* at Barberspan Bird Sanctuary, North West province, South Africa.” *Ostrich* 82 (3): 207–215.

Ma, Z., Cai, Y., Li, B. and Chen, J. (2010). “Managing wetland habitats for waterbirds: an international perspective.” *Wetlands* 30 (1): 15–27.

Mavuti, K.M. (1975). Some aspects of the Biology of the Genera Sigara and Micronecta (Corixidae-Hemiptera) from Lake Nakuru Kenya. *MSc Thesis*. University of Nairobi, Kenya.

Mayfield, H.F. (1975). “Suggestions for calculating nest success.” *The Wilson Bulletin*: 456–466.

McClure, Elliott. (1984). *Bird Banding*. Boxwood Press Pacific Grove, CA.

McCulloch, G. P., Irvine, K., Eckardt, F.D. and Bryant, R. (2008). “Hydrochemical fluctuations and crustacean community composition in an ephemeral saline lake (Sua Pan, Makgadikgadi Botswana).” *Hydrobiologia* 596 (1): 31–46.

McCulloch, M.N. (1991). “Status, habitat and conservation of the St Helena Wirebird Charadrius sanctaehelenae.” *Bird Conservation International* 1 (04): 361–392.

Meehl, G.A., Arblaster, J.M. and Tebaldi, C. (2005). “Understanding future patterns of increased precipitation intensity in climate model simulations.” *Geophysical Research Letters* 32 (18): L18719.

Merkl, O., Forró, L., Bankovics, A., Demeter, A., Korsós, Z. and Murai, É. (1993). “Zoological collectings by the Hungarian Natural History Museum in Africa: a report on the Elgon Expedition, 1992.” *Miscnea zool. hung* 8: 51–64.

Miller, H.W. and Johnson, D.H. (1978). “Interpreting the results of nesting studies.” *The Journal of Wildlife Management*: 471–476.

Mirhosseini, G., Srivastava, P. and Stefanova, L. (2012). “The impact of climate change on rainfall Intensity-Duration-Frequency (IDF) curves in Alabama.” *Regional Environmental Change*: 1–9.

Mitsch, J.W, and Gosselink, J.G. (1993). *Wetlands*. Second ed. Van Nostrand Reinhold, New York, NY.

Møller, A.P. (1987). “Egg predation as a selective factor for nest design: an experiment.” *Oikos*: 91–94.

Morris, D.W. (2003). “How can we apply theories of habitat selection to wildlife conservation and management?” *Wildlife Research* 30 (4): 303–319.

Nasirwa, O. and Bennun, L.A. (2000). “Co-ordinated waterbird counts: the Kenyan experience.” *Ostrich* 71 (1-2): 99–101.

Nichols, J.D. and Kaiser, A. (1999). “Quantitative studies of bird movement: a methodological review.” *Bird Study* 46 (S1): S289–S298.

Nisbet, I.C.T. (2000). “Disturbance, habituation, and management of waterbird colonies.” *Waterbirds*: 312–332.

Owino, A.O. (2002). “Shoreline distribution patterns of Kittlitz’s Plover’ *Charadrius pecuarius* Temminck, at Lake Nakuru, Kenya.” *African Journal of Ecology* 40 (4): 396–398.

Owino, A.O, Bennun, L.A., Nasirwa, O. and Oyugi, J.O. (2002). “Trends in waterbird numbers in the southern Rift Valley of Kenya, 1991-2000.” *Waterbirds* 25 (2): 191–201.

Owino, A.O., Oyugi, J.O., Nasirwa, O.O. and Bennun, L.A. (2001). “Patterns of variation in waterbird numbers on four Rift Valley lakes in Kenya, 1991-1999.” *Hydrobiologia* 458 (1-3): 45–53.

Patten, M.A., and Kelly, J.F. (2010). “Habitat selection and the perceptual trap.” *Ecological Applications* 20 (8): 2148–2156.

Perennou, C. (1991). *African waterfowl census 1991*. International Waterfowl and Wetlands Research Bureau.

Platnick, N.I. and Murphy, J.A. (1987). “Studies on Malagasy spiders. 3, The zelotine Gnaphosidae (Araneae, Gnaphosoidea), with a review of the genus *Camillina*. American Museum novitates; no. 2874.”

Republic of Kenya 2010. Nomination Proposal. Kenya Lakes System in The Great Rift Valley (Elementaita, Nakuru and Bogoria). Whc.unesco.org/uploads/nominations/1060rev.pdf. 541: 37-39.

Robertson, B.A., and Hutto, R.L. (2006). "A framework for understanding ecological traps and an evaluation of existing evidence." *Ecology* 87 (5): 1075–1085.

Robinson, R.A., Clark, N.A., Lanctot, R., Nebel, S., Harrington, B., Clark, J.A., Gill, J.A. (2005). "Long term demographic monitoring of wader populations in non-breeding areas." *Wader Study Group Bulletin* 106: 17–29.

Ruhlen, T.D., Abbott, S., Stenzel, L.E. and Page, G.W. (2003). "Evidence that human disturbance reduces Snowy Plover chick survival." *Journal of Field Ornithology* 74 (3): 300–304.

Schirmel, J, Buchholz, S. and Fartmann, T. (2010). "Is pitfall trapping a valuable sampling method for grassland Orthoptera?" *Journal of Insect Conservation* 14 (3): 289–296.

Schlaepfer, M.A., Runge, M.C. and Sherman, P.W. (2002). "Ecological and evolutionary traps." *Trends in Ecology & Evolution* 17 (10): 474–480.

Shivoga, W.A. (2001). "The influence of hydrology on the structure of invertebrate communities in two streams flowing into Lake Nakuru, Kenya." *Hydrobiologia* 458 (1-3): 121–130.

Shochat, E., Patten, M.A., Morris, D.W., Reinking, D.L., Wolfe, D.H. and Sherrod, S.K. (2005). “Ecological traps in isodars: effects of tallgrass prairie management on bird nest success.” *Oikos* 111 (1): 159–169.

Sunlu, U. (2003). Environmental impacts of tourism. In Conference on the Relationships between Global Trades and Local Resources in the Mediterranean Region, Rabat (Morocco), Apr 2002.

Sutherland, W. J. (2007). “Future directions in disturbance research.” *Ibis* 149 (s1): 120–124.

Svensson, L. (1992). “*Identification Guide to European Passerines*." Published by the author, distributed outside the Nordic Countries by the British Trust for Ornithology, Thetford, Norfolk.

Székely, T. (1992). “Reproduction of Kentish plover Charadrius alexandrinus in grasslands and fish- ponds: the habitat mal-assessment hypothesis.” *Aquila* 99 (3): 59–68.

Székely, T., Kosztolányi, A. and Küpper, C. (2008). “Practical guide for investigating breeding ecology of Kentish plover *Charadrius alexandrinus*.” *University of Bath*.

Székely, T., and Williams, T.D. (1994). “Factors affecting timing of brood desertion by female Kentish plovers *Charadrius alexandrinus*.” *Behaviour*: 17–28.

Thomson, D.L., Furness, R.W. and Monaghan, E. (1998). “Field metabolic rates of kittiwakes *Rissa tridactyla* during incubation and chick rearing.” *Ardea-Wageningen*-86: 169–175.

Tree, A.J. (1974). “Ageing and sexing the Little Stint.” *Safring News* 3 (2): 31–33.

Tree, A.J., Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Parker, V. and Brown, C.J. (1997). “Kittlitz’s Plover.” *The atlas of southern African birds. BirdLife South Africa.* 1: 382–383.

Trenberth, K.E. (2011). “Changes in precipitation with climate change.” *Climate Research* 47 (1): 123.

Underhill, L.G., Tree, A.J., Oschadleus, H.D. and Parker, V. (1999). *Review of ring recoveries of waterbirds in southern Africa*. Avian Demography Unit.

Urban, E.K., Hilary F.C. and Keith, S. (1986). *Birds of Africa Volume II: Gamebirds to Pigeons*. London: Academic Press.

Vareschi, E. and Vareschi, A. (1984). “The ecology of Lake Nakuru (Kenya). IV. Biomass and distribution of consumer organisms.” *Oecologia*: 70–82.

Ward, R. M. (2000). “Darvic colour-rings for shorebird studies: manufacture, application and durability.” *Bulletin-Wader Study Group* 91: 30–34.

Yasué, M. (2005). “The effects of human presence, flock size and prey density on shorebird foraging rates.” *Journal of Ethology* 23 (2): 199–204.

Yasué, M. and Dearden, P. (2006). “The effects of heat stress, predation risk and parental investment on Malaysian plover nest return times following a human disturbance.” *Biological conservation* 132 (4): 472–480.

Zimmerman, D.A, Turner, D.A., Pearson, D.J., Willis, I. and Pratt, H.D. (1996). *Birds of Kenya and northern Tanzania*. Princeton University Press Princeton.

**APPENDICES**

**Appendix 1 Colour ring combination sequencing used in the colour coding birds with Davic rings.**

| | | | | | |
|---|---|---|---|---|---|
| MYYY | MYWR | MBRY | MRRB | MWRY | MPPY |
| MYYR | MYWP | MBRR | MRRW | MWRR | MPPR |
| MYYP | MYWB | MBRP | MRBY | MWRP | MPPP |
| MYYB | MYWW | MBRB | MRBR | MWRB | MPPB |
| MYPR | MBYY | MBRW | MRBP | MWRW | MPPW |
| MYPP | MBYR | MBBY | MRBB | MWBY | MPRY |
| MYRR | MBYP | MBBR | MRBW | MWBR | MPRR |
| MYRP | MBYB | MBBP | MRWY | MWBP | MPRP |
| MYRB | MBYW | MRRR | MRWR | MWBB | MPRB |
| MYRW | MBPY | MRPB | MRWP | MWBW | MPRW |
| MYYW | MBPR | MRYY | MRWB | MWWY | MPBY |
| MYPY | MBPP | MRYR | MWYY | MWWR | MPBR |
| MYPB | MBPB | MRYP | MWYR | MWWP | MPBP |
| MYPW | MBPW | MRYB | MWYP | MWWB | MPBB |
| MYRY | MBBB | MRYW | MWYB | MWWW | MPBW |
| MYBY | MBBW | MRPY | MWYW | MRWW | MPWY |
| MYBR | MBWY | MRPR | MWPY | MPYY | MPWR |
| MYBP | MBWR | MRPP | MWPR | MPYR | MPWP |
| MYBB | MBWP | MRPW | MWPP | MPYP | MPWB |
| MYBW | MBWB | MRRY | MWPB | MPYB | MPWW |
| MYWY | MBWW | MRRP | MWPW | MPYW | YMYW |

Colour codes for the rings

M = Metal, Y = Yellow, R = Red, B = Blue, P = Purple, W = White,

## Appendix 2 List of individual birds ringed and biometric information recorded at Lakes Nakuru and Elementeita.

| Date | Ring Number | Age | Wing | Head | Tarsus | Weight | Bill | Tail | Notes | Colour Code |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Elmenteita** | | | | | | | | | | |
| 18-May-05 | A72703 | Juv | | 23.2 | 21 | 5 | 5.4 | | Pullus | MBBB |
| 18-May-05 | A72704 | Juv | | 22.9 | 22 | 5 | 5.5 | | Pullus | MBBR |
| 18-May-05 | A72705 | Juv | | 24.2 | 21.8 | 6 | 6.3 | | | MBPB |
| 18-May-05 | A72706 | Juv | | 23 | 23.5 | 5.5 | 5.6 | | | MBPP |
| 18-May-05 | A72707 | Juv | | 26 | 22.3 | 7.5 | 6.1 | | | MBPR |
| 18-May-05 | A72708 | Juv | | 25.6 | 22.1 | 7 | 6.3 | | | MBPY |
| 18-May-05 | A72709 | Juv | 52 | 34.2 | 29.4 | 17.5 | 10.3 | | | MBPW |
| 19-May-05 | A72710 | Juv | | 23.2 | 22.1 | 5.5 | 5.8 | | | MBYP |
| 19-May-05 | A72711 | Juv | | 24.6 | 21.8 | 6 | 6.3 | | | MBYB |
| 19-May-05 | A72712 | Juv | | 23.5 | 23.2 | 5.5 | 5.6 | | | MBYP |
| 19-May-05 | A72713 | Juv | | 24.8 | 21.8 | 6 | 6.8 | | | MBYR |
| 19-May-05 | A72714 | Ad | 106 | 38.8 | 34 | 35 | 13 | | | MBYY |
| 19-May-05 | A72715 | Ad | 106 | 38.5 | 33 | 34 | 14 | | | MBYW |
| 18-Jun-05 | A72716 | Juv | | 25 | 21.8 | 6.1 | 5.9 | | | MBWW |
| 18-Jun-05 | A72717 | Juv | | 24.4 | 21.9 | 5.8 | 6.4 | | | MBWP |
| 18-Jun-05 | A72718 | Juv | | 24.2 | 21.9 | 6.1 | 6.2 | | | MBWR |
| 25-Jun-05 | A72716 | Juv | | 28.8 | 27.3 | 12.6 | 9.7 | | Re-trap | MBWW |
| 25-Jun-05 | A72717 | Juv | | 28.7 | 26.5 | 11.4 | 9.7 | | Re-rap | MBWP |
| 25-Jun-05 | A72721 | Juv | | 29 | 26.8 | 11.1 | 9.6 | | | MBWB |
| 25-Jun-05 | A72722 | Juv | | 28.7 | 25.8 | 10.6 | 8.3 | | | MBWY |
| 6-Sep-05 | A72732 | Juv | | 25.2 | 22.3 | 7 | 6.5 | | | MRRB |
| 10-Sep-05 | A72732 | Juv | | 27.5 | 23.3 | 8.5 | 7.9 | | Re-trap | MRRB |
| 10-Sep-05 | A72733 | Juv | | 25.4 | 22.3 | 7 | 6.1 | | | MRYY |
| 4-Feb-06 | A67931 | Ad | 103 | 37.1 | 31.2 | 29 | 14.6 | 0 | | |
| 4-Feb-06 | A67932 | Ad | 103 | 39.8 | 31.9 | 33.5 | 13.9 | 1 | Sub Adult | |
| 19-Feb-06 | A67935 | Ad | 102 | 39.2 | 32.5 | 33.8 | 13.9 | | | |
| 20-Feb-06 | A67939 | Ad | 108 | 40.1 | 34.5 | 36.5 | 12.7 | | | |
| 12-May-06 | A72740 | Ad | 105 | 38.5 | 32.3 | 31 | 13.5 | W | Parent to A72799 and A72800 | MBRP |
| 12-May-06 | A72799 | Juv | | 25.1 | 21.9 | 6.6 | 6.3 | | | MBRR |
| 12-May-06 | A72800 | Juv | | 25.5 | 21.8 | 7.4 | 6.7 | | Sibling to A72799 | MBRY |
| 14-May-06 | A72741 | Ad | 106 | 41.7 | 35.6 | 34.6 | 13.5 | W | incubating | MBRB |
| 24-May-06 | A72742 | Ad | 106 | 40.1 | 34.3 | 33 | 13.8 | W | incubating | MBRW |
| 24-May-06 | A72743 | Juv | | 28.4 | 25.7 | 9.5 | 8.3 | | | MBBY |
| 24-May-06 | A72744 | Juv | | 28.7 | 25.4 | 9.6 | 8.2 | | | MBBR |
| 24-May-06 | A72745 | Juv | | 29.1 | 26.9 | 10.9 | 9.5 | | | MBBP |
| 24-May-06 | A72746 | Juv | | 28.4 | 26.7 | 10.6 | 8.5 | | | MPYY |
| 24-May-06 | A72747 | Ad | 101 | 39.6 | 32.8 | 29.8 | 13.2 | W | Parent to A72743 and A72744 | MPYR |
| 24-May-06 | A72748 | Ad | 105 | 40.2 | 35.2 | 27 | 14.5 | W | Parent to A72745 and A72746 | MPYP |
| 24-May-06 | A72749 | Juv | | 25.8 | 23.5 | 7.1 | 6.9 | | | MPYB |
| 24-May-06 | A72750 | Ad | 104 | 40 | 34.8 | 36.5 | 12.5 | W | Pair with A72751 incubating nest | MPYW |
| 24-May-06 | A72751 | Ad | 106 | 40 | 32.4 | 37.4 | 13.2 | W | Pair with A72750 (incubating nest) | MPPY |

| Date | Ring Number | Age | Wing | Head | Tarsus | Weight | Bill | Tail | Notes | Colour Code |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Elmenteita** | | | | | | | | | | |
| 24-May-06 | A72752 | Juv | | 23.5 | 22 | 5 | 5.6 | | | MPPR |
| 24-May-06 | A72753 | Juv | | 23.7 | 21.8 | 5.6 | 5.8 | | | MPPP |
| 24-May-06 | A72754 | Ad | 102 | 40.4 | 33.6 | 34.2 | 13.2 | W | Parent to A72752 and A72753 | MPPB |
| 24-May-06 | A72800 | Juv | | 32.4 | 28.3 | 15 | 10.5 | | Re-trap | MBRY |
| 26-May-06 | A72755 | Ad | 101 | 39.9 | 33.1 | 35 | 12.5 | W | | MPPW |
| 26-May-06 | A72756 | Ad | 102 | 40.2 | 35.7 | 36.6 | 12.9 | W | Partner to A72742 | MPRY |
| 26-May-06 | A72757 | Ad | 102 | 39.4 | 33.7 | 34.5 | 12.5 | W | | MPRR |
| 26-May-06 | A72758 | Ad | 106 | 40.5 | 32.8 | 34.5 | 12.8 | W | | MPRP |
| 26-May-06 | A72759 | Ad | 106 | 38.8 | 34.2 | 35.6 | 11.8 | W | Partner to A72755 | MPRB |
| 13-Jul-06 | A72760 | Juv | | 32.6 | 28.5 | 15.5 | 9.4 | | | MPRW |
| 13-Jul-06 | A72761 | Juv | | 33.1 | 28 | 15 | 9.4 | | | MPBY |
| 13-Jul-06 | A72762 | Ad | 110 | 42.1 | 33 | 40.5 | 13.7 | 1 | | MPBR |
| 13-Jul-06 | A72763 | Juv | 58 | 34.5 | 32.2 | 19.5 | 10.5 | | | MPBP |
| 13-Jul-06 | A72764 | Juv | | 28.5 | 25.5 | 9.5 | 8.5 | | | MPBB |
| 13-Jul-06 | A72765 | Juv | 48 | 34.2 | 29.7 | 19 | 10.5 | 1 | | MPBW |
| 13-Jul-06 | A72766 | Juv | 45 | 34.8 | 30 | 19 | 9.9 | 1 | | MPWY |
| 13-Jul-06 | A72767 | Juv | | 30 | 26 | 10.5 | 8.7 | | | MPWR |
| 13-Jul-06 | A72768 | Juv | | 29 | 24.9 | 10.5 | 8 | | | MPWP |
| 13-Jul-06 | A72769 | Ad | 105 | 40.5 | 32.7 | 34 | 13.5 | SW | | MPWB |
| 15-Jul-06 | A72770 | Juv | | 31.5 | 27.4 | 14 | 9.8 | | | MPWW |
| 15-Jul-06 | A72771 | Juv | 70 | 38 | 34.2 | 25 | 10.8 | | | MWYY |
| 15-Jul-06 | A72772 | Juv | 71 | 36.5 | 30.5 | 20.5 | 12 | | | MWYR |
| 15-Jul-06 | A72773 | Ad | 100 | 40 | 33.5 | 32.5 | 13.5 | SW | | MWYP |
| 15-Jul-06 | A72774 | Juv | | 26 | 23.1 | 8 | 7.6 | | | MWYB |
| 15-Jul-06 | A72775 | Juv | | 26.5 | 22.8 | 7.5 | 7.4 | | | MWYW |
| 17-Jul-06 | A72776 | Juv | | 22.7 | 22.4 | 5 | 5.7 | | | MWPY |
| 17-Jul-06 | A72777 | Juv | 56 | 34.1 | 29.1 | 17 | 10.1 | 1 | | MWPR |
| 17-Jul-06 | A72778 | Ad | 105 | 38.7 | 31.6 | 34 | 12.5 | | | MWPP |
| **Lake Nakuru** | | | | | | | | | | |
| 23-Mar-05 | A72701 | Juv | | 32.1 | 28.3 | 16.5 | 9.8 | | About a week old | MYYY |
| 23-Mar-05 | A72702 | Juv | | 28.6 | 26.3 | 12 | 9.6 | | About a week old | MYYR |
| 18-Jun-05 | A72719 | Juv | | 24.9 | 21.9 | 6.2 | 6.6 | | Sibling to A72720 | YMYW |
| 18-Jun-05 | A72720 | Juv | | 25 | 21.8 | 5.9 | 5.9 | | | MYYP |
| 13-Aug-05 | A72723 | Juv | | 31.1 | 27.3 | 13.5 | 9.6 | | | MYYB |
| 13-Aug-05 | A72724 | Juv | | 28.9 | 26.3 | 13.5 | 9.5 | | | MYYR |
| 13-Aug-05 | A72725 | Juv | 71 | 36.7 | 31.7 | 22 | 13 | | Sibling to A72728 | MYPP |
| 22-Aug-05 | A72726 | Juv | | 25.5 | 22.3 | 7 | 6.7 | | | MYRR |
| 22-Aug-05 | A72727 | Juv | | 24.7 | 21.9 | 6.5 | 6.7 | | | MYRB |
| 22-Aug-05 | A72728 | Juv | 71 | 37.1 | 34.1 | 22.5 | 13.2 | | Sibling to A72725 | MRRR |
| 28-Aug-05 | A72729 | Juv | | 31.5 | 26.6 | 12.5 | 9.7 | | | MYRW |
| 28-Aug-05 | A72730 | Juv | | 26.2 | 24.3 | 9 | 8.2 | | | MYRP |
| 28-Aug-05 | A72731 | Juv | | 26.8 | 25.1 | 8.5 | 7.6 | | | MYPR |
| 25-Sep-05 | A72735 | Juv | | 26.1 | 24.6 | 8.5 | 8.2 | | | MYPY |
| 25-Sep-05 | A72736 | Juv | | 28 | 25.2 | 9.5 | 7.8 | | | MYPB |
| 25-Sep-05 | A72737 | Juv | | 30.6 | 27.3 | 13 | 9.6 | | Lone chick | MYPY |
| 25-Sep-05 | A72738 | Juv | | 28.9 | 26.6 | 11.2 | 9.7 | | Lone chick | MYRY |
| 26-Sep-05 | A72739 | Juv | 71 | 37.8 | 31.7 | 20.7 | 12.4 | | Lone chick | MYBY |

**Appendix 3 Example of random X and Y values generate by excel for sampling using quadrats.**

| Plot 1 | | | | | | | Plot 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blk1 | | Blk2 | | Blk3 | | | Blk1 | | Blk2 | | Blk3 | |
| X | Y | X | Y | X | Y | | X | Y | X | Y | X | Y |
| 100 | 42 | 48 | 17 | 73 | 21 | | 44 | 8 | 49 | 2 | 64 | 16 |
| 6 | 43 | 15 | 41 | 48 | 14 | | 43 | 37 | 15 | 32 | 51 | 42 |
| 82 | 31 | 37 | 20 | 9 | 28 | | 65 | 46 | 73 | 8 | 34 | 34 |
| 14 | 4 | 60 | 38 | 62 | 31 | | 99 | 11 | 86 | 25 | 89 | 22 |
| 34 | 16 | 11 | 44 | 33 | 42 | | 69 | 11 | 18 | 30 | 24 | 15 |
| 48 | 6 | 4 | 31 | 49 | 41 | | 7 | 45 | 96 | 1 | 40 | 17 |
| 87 | 29 | 3 | 31 | 74 | 30 | | 55 | 12 | 61 | 18 | 64 | 29 |
| 32 | 30 | 78 | 28 | 59 | 39 | | 79 | 31 | 59 | 22 | 37 | 33 |
| 27 | 22 | 97 | 39 | 96 | 23 | | 43 | 32 | 92 | 25 | 88 | 5 |
| 90 | 20 | 15 | 24 | 26 | 33 | | 18 | 26 | 36 | 44 | 53 | 25 |
| 10 | 23 | 22 | 7 | 30 | 11 | | 37 | 48 | 89 | 9 | 3 | 8 |
| 33 | 24 | 61 | 7 | 35 | 30 | | 97 | 14 | 97 | 3 | 61 | 11 |
| 53 | 7 | 61 | 33 | 44 | 34 | | 96 | 36 | 68 | 15 | 58 | 15 |
| 32 | 23 | 86 | 30 | 48 | 39 | | 97 | 32 | 39 | 34 | 8 | 15 |
| 85 | 8 | 49 | 38 | 86 | 7 | | 55 | 45 | 98 | 29 | 77 | 3 |
| 22 | 37 | 6 | 1 | 56 | 32 | | 39 | 5 | 15 | 12 | 50 | 24 |
| 64 | 12 | 75 | 42 | 96 | 24 | | 7 | 49 | 16 | 26 | 91 | 22 |
| 29 | 16 | 84 | 32 | 22 | 8 | | 40 | 21 | 63 | 42 | 85 | 15 |
| 3 | 12 | 62 | 33 | 69 | 42 | | 28 | 3 | 37 | 30 | 62 | 27 |
| 76 | 38 | 15 | 0 | 82 | 46 | | 11 | 34 | 34 | 22 | 69 | 23 |

**Appendix 4 January and July numbers of adult Kittlitz's Plover at Lake Nakuru from the period 1991 to 2006.**

| Site | Date | Sections 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|---|
| Nakuru | 13-Jan-91 | 189 | 44 | 9 | 0 | 76 | 318 |
| | 21-Jul-91 | 80 | 28 | 31 | 14 | 33 | 186 |
| | 12-Jan-92 | 28 | 0 | 4 | 13 | 54 | 99 |
| | 5-Jul-92 | 39 | 22 | 8 | 74 | 67 | 210 |
| | 17-Jan-93 | 31 | 51 | 68 | 5 | 44 | 199 |
| | 4-Jul-93 | 67 | 75 | 22 | 2 | 45 | 211 |
| | 23-Jan-94 | 14 | 5 | 8 | 0 | 10 | 37 |
| | 17-Jul-94 | 24 | 51 | 0 | 0 | 51 | 126 |
| | 15-Jan-95 | 102 | 64 | 32 | 2 | 7 | 207 |
| | 23-Jul-95 | 54 | 92 | 28 | 44 | 104 | 322 |
| | 14-Jan-96 | 2 | 12 | 20 | 0 | 31 | 65 |
| | 7-Jul-96 | 48 | 67 | 51 | 20 | 102 | 288 |
| | 12-Jan-97 | 35 | 14 | 4 | 7 | 76 | 136 |
| | 13-Jul-97 | 37 | 91 | 23 | 54 | 182 | 387 |
| | 11-Jan-98 | 123 | 24 | 29 | 0 | 17 | 193 |
| | 19-Jul-98 | 264 | 0 | 1 | 0 | 0 | 265 |
| | 10-Jan-99 | 172 | 103 | 12 | 0 | 8 | 295 |
| | 11-Jul-99 | 99 | 36 | 42 | 5 | 3 | 185 |
| | 9-Jan-00 | 170 | 116 | 66 | 7 | 185 | 544 |
| | 23-Jul-00 | 59 | 21 | 24 | 4 | 58 | 166 |
| | 7-Jan-01 | 67 | 37 | 158 | 0 | 32 | 294 |
| | 29-Jul-01 | 132 | 107 | 30 | 22 | 116 | 407 |
| | 6-Jan-02 | 119 | 21 | 41 | 0 | 0 | 181 |
| | 28-Jul-02 | 281 | 132 | 11 | 0 | 35 | 459 |
| | 12-Jan-03 | 37 | 20 | 29 | 14 | 23 | 123 |
| | 26-Jul-03 | 30 | 5 | 5 | 0 | 11 | 51 |
| | 11-Jan-04 | 26 | 0 | 43 | 0 | 7 | 76 |
| | 11-Jul-04 | 9 | 17 | 6 | 0 | 2 | 34 |
| | 9-Jan-05 | 25 | 16 | 2 | 0 | 6 | 49 |
| | 31-Jul-05 | 29 | 4 | 0 | 0 | 0 | 33 |
| | 8-Jan-06 | 3 | 33 | 0 | 0 | 0 | 36 |
| | 16-Jul-06 | 0 | 0 | 0 | 0 | 1 | 1 |

**Appendix 5 January numbers of adult Kittlitz's Plover at Lake Elmenteita from the period 1991 to 2006.**

| | | Sections | | | | | |
|---|---|---|---|---|---|---|---|
| Site | Date | 1 | 2 | 3 | 4 | 5 | Total |
| Elmenteita | 4-Jan-91 | 6 | 0 | 0 | 0 | 0 | 6 |
| | 18-Jan-92 | 17 | 0 | 0 | 0 | 0 | 17 |
| | 18-Jan-93 | 6 | 0 | 11 | 6 | 0 | 23 |
| | 22-Jan-94 | 23 | 0 | 0 | 2 | 0 | 25 |
| | 14-Jan-95 | 68 | 0 | 9 | 3 | 0 | 80 |
| | 13-Jan-96 | 5 | 1 | 49 | 2 | 3 | 60 |
| | 11-Jan-97 | 147 | 1 | 37 | 0 | 3 | 188 |
| | 24-Jan-98 | 36 | 0 | 1 | 0 | 4 | 41 |
| | 23-Jan-99 | 11 | 1 | 8 | 5 | 0 | 25 |
| | 22-Jan-00 | 59 | 9 | 20 | 35 | 1 | 124 |
| | 20-Jan-01 | 18 | 6 | 18 | 0 | 0 | 42 |
| | 19-Jan-02 | 24 | 0 | 10 | 1 | 6 | 41 |
| | 25-Jan-03 | 63 | 6 | 49 | 209 | 2 | 329 |
| | 24-Jan-04 | 80 | 23 | 176 | 193 | 0 | 472 |
| | 22-Jan-05 | 12 | 0 | 116 | 7 | 1 | 136 |
| | 21-Jan-06 | 61 | 0 | 25 | 16 | 1 | 103 |

**Appendix 6 Study sections coding, Kittlitz's Plover density and distribution.**

In Chapter 4, the numbers of Kittlitz's Plover are analysed and presented according to the sections in the map below:

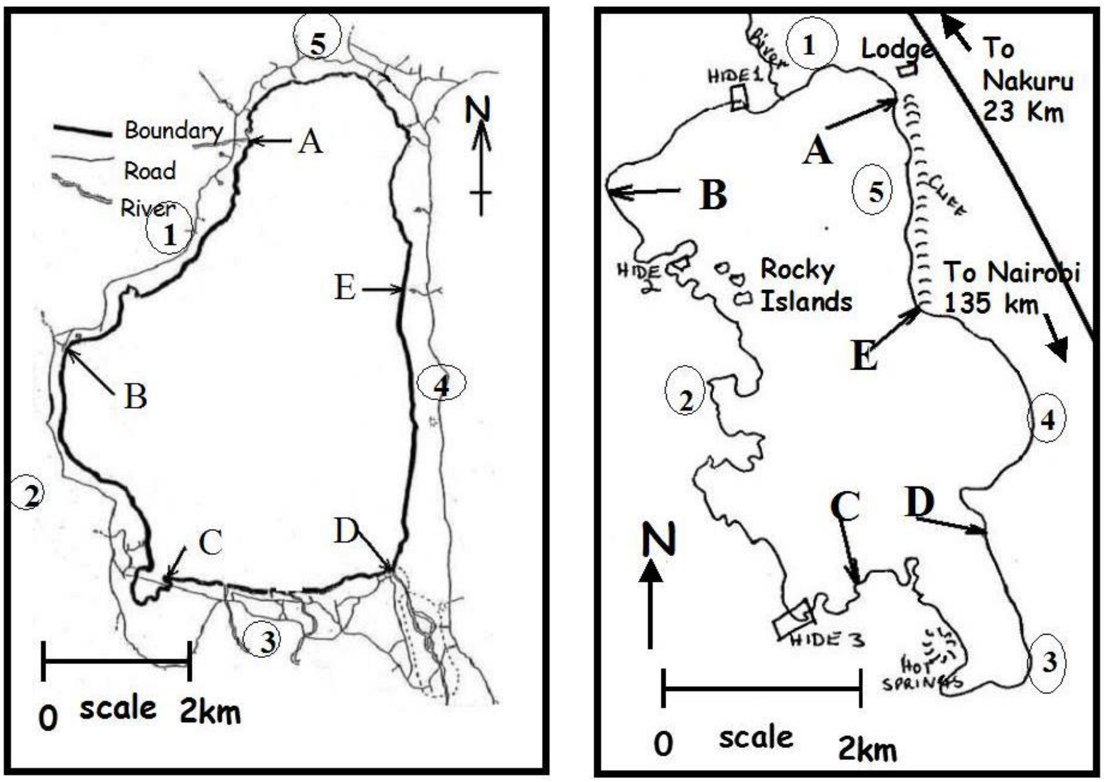



**Figure 10.1 Maps of Lakes Elmenteita and Nakuru showing the study sections.**

In Chapter 4, the sections are numbered as Lake Nakuru (1 to 5) or (NKU1 to NKU5) and Lake Elmenteita (1-5) or (ELT1 to ELT5). The densities of Kittlitz's Plover (numbers per km) obtained in Chapter 4 are reorganised according the codes of sections used in this Appendix. These codes are the ones used to align the results of the thesis from Chapter 5 to 10. With codes as follows:

1. ELM1 the northern section, i.e. from point A to B (Section 1).
2. ELM2 the southern section, i.e. also from point C to E (Sections 3 and 4).
3. NAK1 the western section i.e. from point A to B (Section 1).
4. NAK2 the south-western section i.e. from B to C (Section 2).
5. NAK3 the southern section i.e. from point C to D (Section 3).
6. NAK4 the northern section i.e. from E to A (Section 5)

The density of Kittlitz's Plover (numbers per km) obtained in Chapter 4 are reorganised according the codes of sections used in this Appendix. These codes are the ones used to align the results of the thesis from Chapter 5 to 10. The densities are presented below.

**Appendix 7 Kittlitz's Plover densities (numbers per km) at Lakes Nakuru (NAK) and Elmenteita (ELM) study sections for the period 1991 to 2006.**

| Date | ELM1 | ELM2 | NAK1 | NAK2 | NAK3 |
|---|---|---|---|---|---|
| Length of section (km) | 3.4 | 10.4 | 5.6 | 5.3 | 3.9 |
| Jan-91 | 1.8 | 0.0 | 33.8 | 8.3 | 2.3 |
| Jan-92 | 5.0 | 0.0 | 5.0 | 0.0 | 1.0 |
| Jan-93 | 1.8 | 1.6 | 5.5 | 9.6 | 17.4 |
| Jan-94 | 6.8 | 0.2 | 2.5 | 0.9 | 2.1 |
| Jan-95 | 20.0 | 1.2 | 18.2 | 12.1 | 8.2 |
| Jan-96 | 1.5 | 4.9 | 0.4 | 2.3 | 5.1 |
| Jan-97 | 43.2 | 3.6 | 6.3 | 2.6 | 1.0 |
| Jan-98 | 10.6 | 0.1 | 22.0 | 4.5 | 7.4 |
| Jan-99 | 3.2 | 1.3 | 30.7 | 19.4 | 3.1 |
| Jan-00 | 17.4 | 5.3 | 30.4 | 21.9 | 16.9 |
| Jan-01 | 5.3 | 1.7 | 12.0 | 7.0 | 40.5 |
| Jan-02 | 7.1 | 1.1 | 21.3 | 4.0 | 10.5 |
| Jan-03 | 18.5 | 24.8 | 6.6 | 3.8 | 7.4 |
| Jan-04 | 23.5 | 35.5 | 4.6 | 0.0 | 11.0 |
| Jan-05 | 3.5 | 11.8 | 4.5 | 3.0 | 0.5 |
| Jan-06 | 17.9 | 3.9 | 0.5 | 6.2 | 0.0 |
| Mean density/km | 11.69 | 6.06 | 12.76 | 6.60 | 8.41 |
| SD | 11.24 | 10.06 | 11.53 | 6.46 | 10.19 |

**Appendix 8 Density of Kittliz's Plover by sections at Lakes Nakuru and Elmenteita for the period 1991 to 2006.**

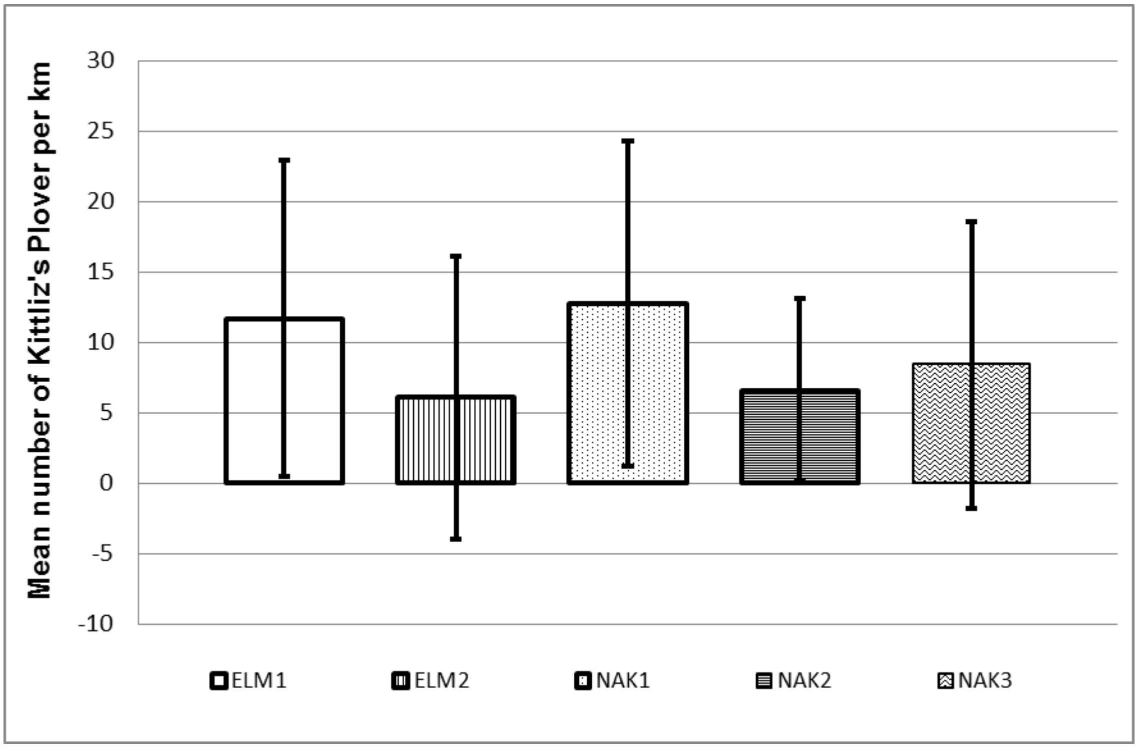



**Figure 10.2 Mean densities of Kittliz's Plover by sections at Lakes Nakuru and Elmenteita for the period 1991 to 2006.** (Mean ±SD, n = 16)

The mean density of Kittlitz's Plover between the sections (ELM1, ELM2, NAK1, NAK2 and NAK3) was not significantly different sections ($F_{4, 75}$ = 1.285, $P$ = 0.234).

## Appendix 9 Monthly number of nests, eggs and chicks located at Lakes Nakuru and Elmenteita for the period 2005 and 2006.

| Site/Year | brood | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Elmenteita** | | | | | | | | | | | | | | |
| 2005 | Nest | 0 | 0 | 0 | 0 | 2 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 9 |
| | Eggs | 0 | 0 | 0 | 0 | 4 | 11 | 0 | 0 | 1 | 0 | 0 | 0 | 16 |
| | Chicks | 0 | 0 | 0 | 0 | 13 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 20 |
| 2006 | Nest | 0 | 0 | 0 | 0 | 10 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 17 |
| | Eggs | 0 | 0 | 0 | 0 | 19 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 31 |
| | Chicks | 0 | 0 | 0 | 0 | 10 | 0 | 13 | 5 | 0 | 0 | 0 | 0 | 28 |
| **Nakuru** | | | | | | | | | | | | | | |
| 2005 | Nest | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 6 |
| | Eggs | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 4 | 2 | 0 | 0 | 0 | 11 |
| | Chicks | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 9 | 5 | 0 | 0 | 0 | 18 |
| 2006 | Nest | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Eggs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chicks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Totals** | | | | | | | | | | | | | | |
| ELM | Nest | 0 | 0 | 0 | 0 | 12 | 6 | 7 | 0 | 1 | 0 | 0 | 0 | 26 |
| | Eggs | 0 | 0 | 0 | 0 | 23 | 11 | 12 | 0 | 1 | 0 | 0 | 0 | 47 |
| | Chicks | 0 | 0 | 0 | 0 | 23 | 5 | 13 | 5 | 2 | 0 | 0 | 0 | 48 |
| NAK | Nest | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 6 |
| | Eggs | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 4 | 2 | 0 | 0 | 0 | 11 |
| | Chicks | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 9 | 5 | 0 | 0 | 0 | 18 |
| **Total** | | | | | | | | | | | | | | |
| All | Nest | 0 | 0 | 0 | 0 | 12 | 9 | 7 | 2 | 2 | 0 | 0 | 0 | 32 |
| | Eggs | 0 | 0 | 0 | 0 | 23 | 16 | 12 | 4 | 3 | 0 | 0 | 0 | 58 |
| | Chicks | 0 | 0 | 2 | 0 | 23 | 7 | 13 | 14 | 7 | 0 | 0 | 0 | 66 |

## Appendix 10 Summary of indices and data collected from sections of Lakes Nakuru and Elmenteita.

| Description | Lake Elmenteita | | Lake Nakuru | | |
|---|---|---|---|---|---|
| | ELM1 | ELM2 | NAK1 | NAK2 | NAK3 |
| Shoreline length | 3.4 | 10.4 | 5.6 | 5.3 | 3.9 |
| Mean density of Kittlitz's Plover (birds per km) | 11.7 | 6.1 | 12.8 | 6.6 | 10.3 |
| Average numbers of Kittlitz's Plover counted in January (1991 to 2006) | 39.75 | 63.00 | 71.44 | 35.00 | 32.81 |
| Average numbers of Kittlitz's Plover counted in January (1991 to 2002) | 35.00 | 18.08 | 87.67 | 40.92 | 37.58 |
| Average numbers of Kittlitz's Plover counted in January (2003 to 2006) | 54.00 | 197.75 | 22.75 | 17.25 | 18.50 |
| Mean frequency of herbivores foot prints (X100) | 50.64 | 10.71 | 13.33 | 85.00 | 11.00 |
| Mean frequency of human footprints (x100) | 0.23 | 1.67 | 7.50 | 0.00 | 1.00 |
| Mean frequency of tyre tracks (X100) | 1.85 | 4.76 | 48.33 | 0.00 | 38.00 |
| Mean frequency of litter (solid waste) (X100) | 0.46 | 0.71 | 0.00 | 0.00 | 0.00 |
| Mean frequency of predator footprints (X100) | 2.84 | 0.71 | 0.83 | 6.00 | 1.00 |
| Mean frequency of dung (x100) | 8.86 | 2.14 | 0.00 | 37.00 | 9.00 |
| Number of natural nests found in 2005 | 5 | 4 | 1 | 5 | 0 |
| Number of natural nests found in 2006 | 0 | 17 | 0 | 0 | 0 |
| Total number of natural nests found in 2005 and 2006 | 5 | 21 | 1 | 5 | 0 |
| Average number of nests found for 2005 and 2006 | 2.5 | 10.5 | 0.5 | 2.5 | 0 |
| Number of eggs found in 2005 | 9 | 7 | 1 | 10 | 0 |
| Number of eggs found in 2006 | 0 | 31 | 0 | 0 | 0 |
| Total number of eggs found for 2005 and 2006 | 9 | 38 | 1 | 10 | 0 |
| Average number of eggs found in 2005 and 2006 | 4.5 | 19 | 0.5 | 5 | 0 |
| Number of chicks found in 2005 | 7 | 13 | 12 | 6 | 0 |
| Number of chicks found in 2006 | 0 | 28 | 0 | 0 | 0 |
| Total number of chicks found in 2005 and 2006 | 7 | 41 | 12 | 6 | 0 |
| Average number of chicks found in 2005 and 2006 | 3.5 | 20.5 | 6 | 3 | 0 |
| Mayfield Daily Mortality Rate | 0.030 | 0.029 | 0.032 | 0.036 | 0.036 |
| Mayfield Daily Survival Rate | 0.970 | 0.971 | 0.968 | 0.964 | 0.964 |
| Mayfield Estimated Nest Survival | 0.432 | 0.438 | 0.401 | 0.361 | 0.361 |
| Number of dummy nests at day zero | 52 | 32 | 20 | 21 | 20 |
| Dummy nests that survived incubation period (28 days) | 9 | 6 | 2 | 0 | 0 |
| Mean number of spiders captured by pitfall traps | 2.7 | 7 | 5.5 | 1.5 | 1 |
| Mean number of Coleoptera captured by pitfall traps | 1180.7 | 665.8 | 788 | 739.5 | 297 |
| Mean number of Dermaptera captured by pitfall traps | 39.3 | 29.8 | 95 | 41.5 | 19 |
| Mean number of Diptera captured by pitfall traps | 3.7 | 2 | 4.5 | 6 | 1 |
| Mean number of Hemiptera captured by pitfall traps | 0.7 | 0 | 0 | 0 | 0 |
| Mean number of Hymenoptera captured by pitfall traps | 0.3 | 4.3 | 2.5 | 2.5 | 0 |