The IUCN Wetlands Programme

Wetlands of Kenya

Proceedings of a Seminar on Wetlands of Kenya

S.A. Crafter, S.G. Njuguna and G.W. Howard

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IUCN Wetlands Programme

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The core of the Programme is a series of field projects which develop the methodologies for wetland management, in particular in the countries of the developing world where wetlands are used intensively by local communities which depend upon these for their well-being. Related strategic and policy initiatives draw upon the results of these projects and present their conclusions in a form useful for government decision makers and planners.

The activities of the Programme are designed on the basis of the concerns and information provided by IUCN members. To facilitate this, the Programme works through IUCN's regional offices. The Programme also works closely with the major development assistance agencies to ensure that conservation considerations are adequately addressed in their projects.

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It is coordinated from the IUCN Headquarters in Switzerland, with regional coordinators in Central America, South America, Brazil, West Africa, southern Africa and Asia.

Wetlands of Kenya

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Foreword

The Kenya Wetlands Working Group was set up to "promote the conservation and wise use of wetland habitats in Kenya, according to the guidelines set out in the Ramsar Convention on Wetlands of International Importance...". The group arose from recommendations made at a workshop on *Wetlands and Waterbirds in Eastern Africa* held in Uganda in March 1990, under the auspices of the International Waterfowl and Wetlands Research Bureau and the Institute of Environment and Natural Resources of Makerere University, Kampala. The Kenyan delegation to that workshop resolved to set up a national wetlands group and to become involved in the IWRB African Waterfowl Censuses. This was achieved by January 1991, when the Kenyan group carried out the first coordinated waterfowl census in association with 14 other African countries. Later in that year the group expanded its interests to include wetland conservation and management for wise use and became the KWWG, a sub-group of the East African Natural History Society.

KWWG planned the Seminar on the Wetlands of Kenya and held the meeting at the Louis Leakey Memorial Auditorium in the National Museums of Kenya, Nairobi, with assistance from the IUCN Wetlands Programme and the IUCN Eastern Africa Regional Office. The gathering of 130 people from 42 institutions lasted three days and saw 20 papers presented and discussed. The Seminar was kindly opened by a representative of Dr Richard Leakey, Director, Kenya Wildlife Service and was graciously closed by the Director of the National Museums of Kenya, Dr M. Isahakia. On the last afternoon the participants divided into four groups to discuss issues raised by the presentations and to make recommendations for further actions on wetland conservation and management in Kenya. These resolutions were discussed and refined in plenary session and were then printed and circulated to participants.

The present proceedings of the Seminar have been funded by the IUCN Wetlands Programme and prepared by KWWG. One of the main intentions of the Seminar was to gather contemporary knowledge and experience of Kenyan wetlands and to publish this as a source book. KWWG hopes that these proceedings will become a starting point for further research activities and act as a background document to begin the process of wise use of wetlands in the country. The Recommendations will act as a stimulus to KWWG for futher action and may initiate general wetland conservation and management activities in government and elsewhere. The need for a national wetlands programme is mentioned in the Recommendations and is backed up by many contributors to the Seminar in their calls for an integrated process for wetland management in Kenya.

KWWG thanks all the contributors, participants and supporters for making the Seminar a success and hopes that the proceedings will help to spread the idea of wise and sustainable use of wetlands in Kenya, in the Eastern Africa Region and further afield.

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Definition and overview

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The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat defines 'wetlands' in its Article 1 as

> "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres"

(Dugan, 1990).

This is the definition used at the Kenya Wetlands Seminar because it groups together ecosystems that have some common management needs as well as those sharing characteristics associated with water.

The Ramsar definition covers a range of marine, coastal and inland habitats which in Kenya include deltas, estuaries, mangroves and marine mud flats as well as marshes, swamps, bogs, floodplains, shallow lakes and the edges of deep lakes and rivers. The marine wetlands can include seagrass beds and coral reefs, provided that these are not deeper than six metres - a depth that was chosen to make sure that all wetlands contain vegetation influenced by light. This vegetation in shallow lakes can be submerged, emergent or floating tracheophytes in fresh-water environments, or it can be single-celled algae and blue-greens in salty or soda lakes - but in every case there is some plant life associated with the wetlands. It is the association of water and light and soil and plants that typifies the various wetlands of Kenya - which are described in detail in the following papers. Thus the edges of deep lakes and large rivers are regarded as wetlands if they contain vegetation and are not deeper than six metres. Some wetlands have water that is standing above ground all year round while others are seasonal in that water comes and goes. Fluctuations in water level of wetlands can vary from several metres deep to some centimetres below ground - but they are still seen as wetlands if they have wetland plants, at least at some time in the yearly cycle of wet and dry.

The distribution of the larger wetlands of Kenya is shown in Figure 1; most of these are described in subsequent papers. Kenya's most famous (and most researched) wetlands are the shallow lakes of the Gregory Rift Valley, the edges of Lake Victoria and the mangrove forests of the coast (Figure 1). Information about these and many other Kenyan wetlands was gathered and summarised by Hughes and Hughes (1992)

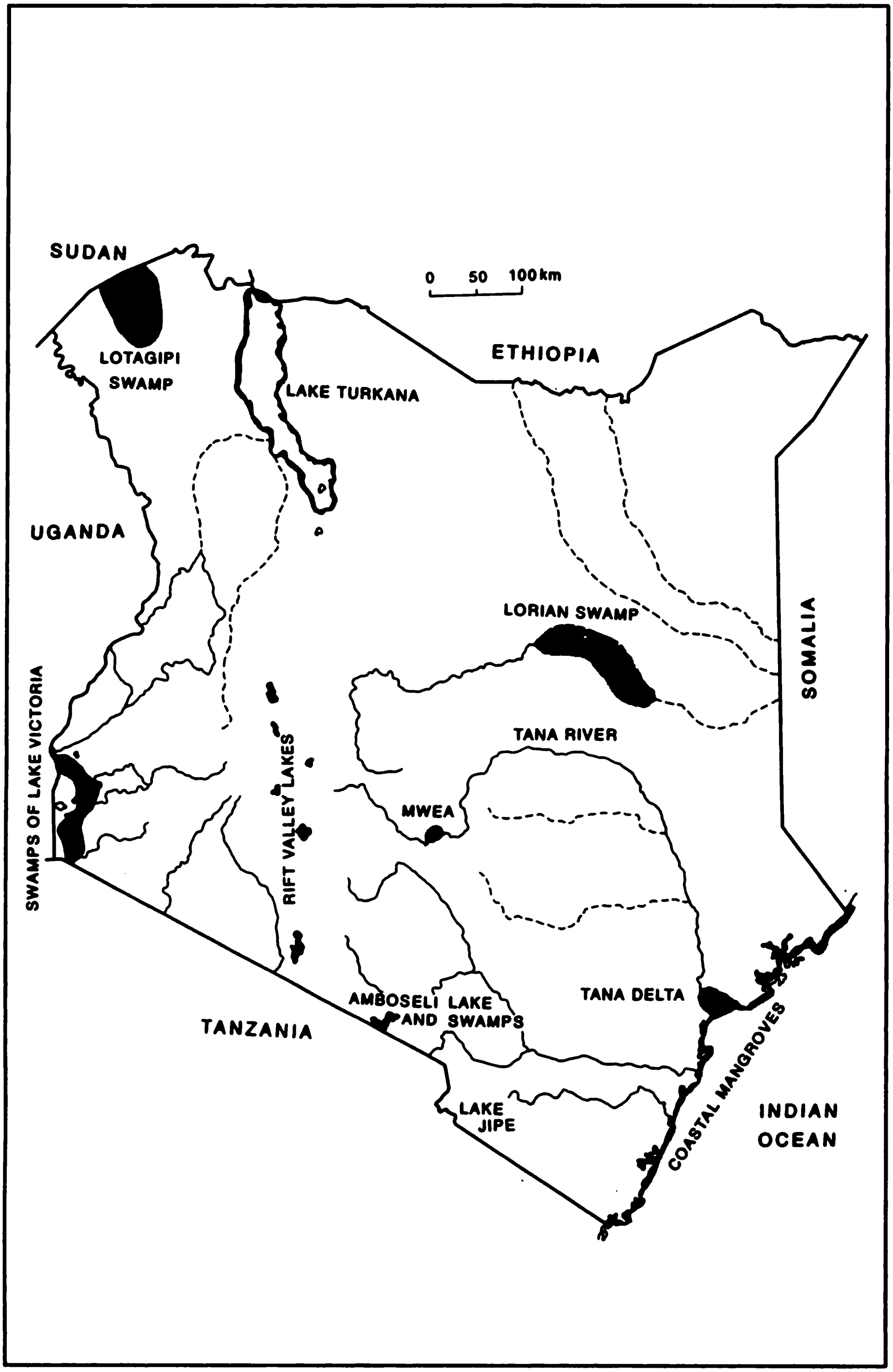

Figure 1 Map of major wetlands of Kenya

in a directory that was published after the present Seminar. Their directory enlarged upon the account of selected wetlands given by Burgis and Symoens (1987) and the general description of African wetlands by Denny (1991) - which was also published after the KWWG Seminar.

There are many hundreds of small wetlands (such as swamps, small lakes, soaks and riverine floodplains) that are distributed throughout the wetter areas of the country and which could not be placed on such a map as Figure 1. Generally these are found in the higher rainfall areas of the west and central parts of Kenya where water is relatively abundant. But there are some very important small wetlands that occur in the drier parts as a result of the occasional flows of ephemeral rivers or as the output of springs from distant water sources. It is these wetlands in drylands that are so important to people, livestock and wildlife as refuges in times of drought. The conflicts that can arise on these small wetlands are similar in nature, but of a smaller scale, to the conflicts that can arise for access to the resources in the larger wetlands where water supply, hydropower generation, irrigation, livestock, fisheries, conservation and tourism can all compete as legitimate uses. The potential conflicts for these 'economic' uses of larger wetlands tend to mask the other more traditional uses that residents and local people have for the same ecosystems. Such activities as honey gathering, collection of wetland plants for food and shelter, plants for basketry and building, small-scale swamp fisheries, hunting and ceremonial activities all constitute uses of wetlands made by local people in Kenya.

Wetlands are many things to many people - once they are understood and appreciated as valuable ecosystems. In Kenya that understanding is well advanced and wetlands have been appreciated as habitats that are necessary for various economic and conservation activities. But, of necessity, the appreciation of wetlands as providers of products and services and habitats comes from many different sectors of society and of government. This has resulted in planning for wetland management being uncoordinated and thus sometimes favouring one or two particular users. It is the hope of this publication that some of the information presented here will enable a better appreciation of the functions, uses and values of wetlands in Kenya. In this way KWWG hopes to assist those who will manage wetlands in future to plan for the wise and sustainable use of these ecosystems and allow for multiple utilisation for all concerned.

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Origins and geomorphology of Kenya's wetlands

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Summary

From the geomorphological point of view, there are two conditions necessary to create a wetland; the topographic situation (a slope or depression that permits the retention of water at or very close to the earth's surface) and the hydrologic condition (a perennial or seasonal supply of fresh or salt water). Based largely on topographic criteria, wetlands in Kenya can be divided into five major classes: (1) marine, (2) deltaic, (3) riverine, (4) lacustrine and (5) plateau, and into two minor classes: (6) artificial wetlands and (7) montane peat bogs. Each of the above categories of wetland is described, with some indication of how they came into existence and of the current natural and anthropogenic factors influencing their evolution.

It is concluded that although Kenya has a great variety of wetlands, they are not evenly distributed over the country. Most of them occur within the well-watered areas; the coastal strip, the highlands and the Lake Victoria basin. The extensive plateau lands of Kenya are poorly supplied with wetlands, due to the generally low rainfall, high evaporation and the absence of suitable topographic sites.

Introduction

The definition of wetlands as provided by the Ramsar Convention and described in the Preface has been followed in this paper.

Geomorphology is the study of the origin and evolution of the landforms of the earth's surface, in particular those formed by the surface processes of denudation. Geomorphologists interpret landscapes as being formed by the interaction of two sets of processes; the internal or endogenic processes such as vulcanism and tectonism, and the external or exogenic processes brought about by the agents of denudation: water, wind and ice.

From the geomorphological point of view there are two conditions necessary to create a wetland. One is the topographic situation; the presence of a slope or depression that permits the retention of water at or very close to the earth's surface. The second is the hydrologic condition; the perennial or seasonal supply of fresh or salt water. In providing a geomorphological account of the wetlands of Kenya, the topographic situation shall be used as the basis of classification. On this basis wetlands can be divided into five major classes: (1) marine, (2) deltaic, (3) riverine, (4) lacustrine and (5) plateau; and two minor classes: (6) artificial wetlands and (7) montane peat bogs. It should be noted that this is a broad classification and that there are likely to be some areas of overlap between the different classes.

Since geomorphology is concerned with the origin and evolution of landforms, attention has also been given to this aspect of Kenya's wetlands. In terms of the geological time scale (age of the earth *circa* 4.5 billion years, oldest known rocks *circa* 3.4 billion years, oldest rocks of Kenya *circa* 2.9 billion years) most wetlands are short term, almost ephemeral, features whose rates of change are very rapid; many of them are features whose ages may be measured in tens or hundreds of thousand years. Both the topographic and the hydrologic conditions that define a wetland may be subject to rapid change. Topographic conditions may change through downfaulting or downwarping of the earth's crust or through the extrusion of volcanic rock that creates or destroys a basin. Hydrologic conditions may change through continued downcutting by a river, by diversion of water from one drainage basin to another or through climatic change.

In the last few thousand years, the activities of human beings, firstly in draining wetlands for agricultural purposes and more recently in several other ways, have also influenced wetlands. Thus a geomorphological approach to wetlands should include the dynamic element and an attempt to evaluate the changes, both natural and anthropogenic, which they may be undergoing.

Marine Wetlands

Open coastlines

On open coastlines, where the ocean is the only significant source of water and the topography is that of the shore, either an erosional or depositional shoreline occurs. On an erosional shoreline, waves armed with sand and pebbles, create cliffs and wave-cut platforms. These are termed high-energy shorelines and the plant and animal life is necessarily adapted to a very dynamic situation, subject to the physical stresses exerted by moving water and to frequent drastic changes in wetness. Some parts of the Kenya coast have low cliffs cut in coral limestone, subject to wave erosion at high tide, but in general it is a shoreline of low relief, where depositional processes and landforms dominate. Depositional landforms include sand and shingle beaches, mud flats, salt marshes and lagoons, as well as coral reefs which are a particular category of landform created by the constructional activities of coral polyps. Each of the above landforms has its own topographic and hydrologic situation and thus its own wetland ecosystem.

Estuaries

Estuarine areas are inlets at the mouths of rivers where the source of moisture is likely to be partly oceanic (controlled largely by the interaction of the prevalent tidal regime with the local topography) and partly freshwater (controlled by the runoff of the river draining into a particular estuary). The Kenya coast has a number of estuaries which came into existence during recent geological time; examples are at Mombasa, Shimo la Tewa, Kilifi, Turtle Bay and around the Islands of Lamu, Manda and Pate. These estuaries are the flooded lower courses of rivers that about 18,000 years ago flowed down to a shoreline that may have stood about 160 m lower than it does today, and thus several kilometres offshore. This low global sea level occurred during the Last Glacial Maximum when large volumes of ocean water were locked up in the ice sheets that covered large areas in the high and mid-latitudes. As the sea level rose, following the melting of the ice sheets, it flooded the lower courses of these rivers and created narrow estuaries. These estuaries are generally sheltered from high energy waves and receive fine grained sediments from the inflowing streams. Their shores have been colonized by the mangrove trees and associated plants that form the mangrove swamp/ mangrove forest ecosystem that has been well described by Kokwaro (1985).

The rise of global sea level that followed the melting of the ice sheets is believed to have been largely completed about 5,000 years ago and since then the main changes along this coastline have been brought about by the gradual accumulation of sediment in the estuaries. However, it now appears that several anthropogenic factors may bring about significant changes in these ecosystems, which can only be briefly touched on here. The clearing of the mangrove forest for the several purposes outlined by Kokwaro (1985) exposes the soft sediments of the shore to wave erosion. Increasing amounts of terrestrial sediment brought down by rivers such as the Tana and Athi-Galana-Sabaki are fed into the inshore environment, with potentially damaging effects on coral reefs and other living organisms. The rise in global sea levels that many scientists predict as a result of global warming (the 'Greenhouse Effect') will also influence the topography of the Kenya coast and thus the status of the marine wetlands.

Deltaic wetlands

Deltaic wetlands are formed where a river flows into the ocean or into a lake. The flow rate of the river slows, and it divides, so that its power to transport sediment is reduced. Fine sediments accumulate in the river mouth, and for several kilometres offshore, and gradually increase the land area at the expense of the sea. The nature and topography of deltas is very varied, influenced largely by the discharge and sediment load of the river and by the topography and tidal range of the shoreline.

Two major classes of delta recognised by geomorphologists are the arcuate deltas (e.g. the Nile Delta) and the bird's-foot deltas (e.g. the Mississippi Delta). Kenya's major ocean delta is that of the Tana River, an arcuate delta. Lacustrine deltas include the Nzoia-Yala delta on the north shore of Lake Victoria and the Malewa-Gilgil delta on the north shore of Lake Naivasha.

Deltas are low-lying areas composed largely of the sediments brought down by the river. They are subject to frequent flooding and changes in course of the network of distributary streams that cross them. Their input of water is almost entirely from the river itself, although under exceptional circumstances invasions of salt water from the adjacent marine water body may occur. Within a delta there are a large number of micro-enviroments, depending on the age of the different areas of sediment, their altitude and the extent to which they have been colonized by different kinds of vegetation.

The delta is a category of wetland where human influence has been very strong, most notably in draining the land and in controlling the flow of water for irrigation farming. In Kenya the development of irrigation has been relatively slow, but increasing demand for agricultural land has brought about the alteration of some deltas and it is very likely that this will continue.

Riverine wetlands

Riverine wetlands form along the course of a river upstream of its delta. The largest area of such wetlands is usually on the floodplain or lower course of a river, where it is flowing relatively slowly across a wide valley underlain by fine sediments laid down by the river while in flood. Across its floodplain a river usually follows a sinuous, meandering course and swampy areas develop on one or both banks. In some cases, the actual channel may be raised by sedimentation until the river is flowing above its floodplain, separated from it by low sediment ridges called natural levees. Behind these levees standing water may form back-swamps. In a flood period the river may cut across the neck of a curve, leaving a curved lake known as an oxbow lake, which will gradually evolve into a swamp and eventually dry out; such lakes are found along the lower course of the River Tana. A river floodplain is likely to contain a variety of wetland environments, depending on distance from (and height above) the water level and frequency of flooding.

Changes in floodplain topography and hydrology generally take place during floods, when the river changes its course and drops large amounts of sediment on the land. Such flood events, in providing soil and water to the floodplain, play an important part in maintaining its wetland status. Changes due to the damming of a river upstream, which alter the flood regime and sediment input, will be felt in the downstream areas; examples in Kenya are on the Rivers Tana and Turkwell.

Besides the major floodplains, such as those of the Tana and Nyando, there are smaller areas of wetlands along the courses of many Kenyan rivers. In the semi-arid areas the wetland forms the inner margin of the riverine forest, an essential component of the environment for humans and wild and domestic animals. In the deeply dissected areas of the Kenya highlands, narrow strips of wetland occur along the valley bottoms, restricted in area by the steep valley slopes on either side. Such wetlands have long been used for the growing of crops (e.g. sugar cane, arrowroot) and were also sources of clay for traditional potters. Where the valleys widen out, the wetlands are also wider. Examples can be seen along the Nairobi-Thika road, including the now drained and quarried area at Githurai (clayworks) and the papyrus swamps near Ruiru. Another example of such wetlands is the Mwea-Tebere area now used for the growing of paddy rice. All such wetlands are vulnerable to changes in the landuse of their catchment areas; intensive farming without adequate soil and water conservation measures will tend to increase the supply of silt to the wetland and create an erratic, highly seasonal supply of water in place of the previous more regular one.

Lacustrine wetlands

Those wetlands whose source of water is a lake, whether fresh or saline, permanent or seasonal, and whose topographic situation is a lake basin are termed lacustrine wetlands. Kenya has a large number of lakes, of varying topographic and hydrologic character.

Crater lakes

Crater lakes in Kenya include Lakes Simbi, Chala, Sonachi and the lakes on Mount Kenya and Mount Marsabit. A crater lake is formed in an explosion crater or volcanic vent and may be fed entirely by rainfall on the lake surface and the walls of the crater or partly by springs. A newly-formed volcanic crater is generally almost circular and steep-sided and may contain a deep lake with little fringing vegetation. However, most Kenyan crater lakes are small and as time passes sediment is washed down from the steep crater walls and the lake becomes shallower and increasingly colonized by vegetation. Many Kenyan crater lakes are well advanced towards evolution into a swamp, for example Lake Paradise and Sokote Diko (Mount Marsabit) and Lake Nkunga (Mount Kenya).

In geological terms, crater lakes are very short-lived features but the sediments they contain are frequently the source of very valuable data on past vegetation and environmental conditions on their catchments.

Rift Valley lakes

The lakes in the Kenyan Rift Valley are mostly small, rather shallow lakes that occupy gently sloping depressions in the rift floor. In some cases (e.g. the east sides of Lake Bogoria, Lake Nakuru and parts of Lake Magadi) their shorelines are defined by the steep fault scarps typical of rift landscapes, but these scarps do not extend to great depths as they do in Lakes Malawi and Tanganyika. Lake Ol Bolossat is the highest lake within the Kenya Rift Valley, lying on the backtilted Kinangop Plateau at the base of the Sattima Escarpment. The topography of the rift margins is such that these lakes do not have large catchments; streams flowing into the rift arise close to its margins and most drainage from the Kenya highlands is away from the rift valley, to the east or west.

The salinity of the lakes varies greatly, from the highly saline Lake Magadi to freshwater Lake Naivasha, and the nature of the lacustrine wetlands is thus also very varied. The freshness of Lake Naivasha is in part due to its relatively large input of fresh water from the Malewa-Turasha system on the Kinangop Plateau (which is now threatened by the project to supply water to Nakuru, currently under construction). The Rift Valley lakes have fluctuated considerably in water level, area and volume during recent geological time; careful mapping of high shorelines and lake sediments around the slopes of their basins has shown that 10,000 years ago, Lake Nakuru was about 180 m deeper, Lake Naivasha about 120 m deeper and Lake Turkana about 80 m deeper than today. The volumes and levels of these lakes are likely to continue fluctuating widely, with a probable overall downward trend due to global warming and to the intensification of land and water use on their catchments. These changes in lake level will have significant effects on the lacustrine wetlands.

Glacial lakes

On the upper slopes of Mount Kenya there are small glacial lakes (tarns), formed in rocky basins eroded by the former larger glaciers that existed on this mountain several thousand years ago. Examples are Hut Tarn, Tyndall Tarn and the Curling Pond. These are young lakes, probably formed as the ice retreated since the Last Glacial Maximum 18,000 years ago. Due to the low temperatures prevailing at high altitudes, these lakes do not support large wetland ecosystems but they are not completely lacking in plant and animal life.

Lake Victoria

Lake Victoria, formed in a large downwarped basin, falls into a category of its own. It is fed by many rivers and has a large outlet at Jinja, maintaining its low salinity. Lake Victoria, despite its large size, is considered to be a relatively young lake by geological standards; estimates of its age are as low as 100,000 years. As it was formed by the flooding of a dissected landscape, the lake shore is very irregular with many headlands, inlets and islands reflecting the relief of the pre-existing landscape. Such terrain provides a good environment for the accumulation of sediments and the development of freshwater swamps along the lake shores. As time passes, the shoreline of Lake Victoria will gradually lose its irregularity due to the erosion of headlands and the deposition of sediments in inlets. However, such changes will be perceptible on the geological rather than the human timescale, although an increase of sediment load of one of the streams draining into the lake could change the topography of a small area around the stream mouth.

Plateau wetlands

Plateau lakes are shallow bodies of water occurring in depressions on the plateau surface, beyond the margins of the Rift Valley. They may be fed partly by springs, as well as by surface runoff, and are generally highly variable in their surface area and volume; several of them are totally dry for prolonged periods. Examples are Lake Amboseli, Lake Kisima and the Suguta Marmar Swamp near Maralal.

The Chalbi basin, east of Mount Marsabit, lies in one of the most arid areas of Kenya (mean annual rainfall at North Horr is about 150 mm) but following occasional heavy rains it becomes occupied by 'Lake' Chalbi which may be over 500 km^2 in surface area but less than 50 cm deep! (Nyamweru, 1986).

Smaller depressions on the plateau may attract sufficient quantities of rainfall and surface runoff to create seasonal wetlands, distinguished from the surrounding areas by the soil and vegetation. Black cotton soil is the characteristic soil type in the 'vleis', as these shallow depressions have been termed. Larger rainfed swamps are the wetlands found in tectonic depressions on the Kenya highlands, often lying close to the margins of the Rift Valley. These depressions have come into existence due to the reverse faulting that has taken place to produce small troughs or grabens, for instance the Lari depression north of Uplands and Ondiri Swamp near Kikuyu. Little is known of the history and evolution of such features; without a detailed study of their hydrology it may be difficult to distinguish purely rain-fed wetlands from those that are also fed by ground water. Such features are likely to be very vulnerable to climatic change and also to changes in land use on their catchments.

The role of climatic change over the last ten thousand years can be seen in the Lorian Swamp and the Lotogipi Swamp, both of which represent former flowing rivers. The Lorian Swamp was formed due to the failure of the Ewaso Ngiro (north) to maintain its flow to the Indian Ocean, while the Lotogipi Swamp marks the course of an overflow from the high level Lake Turkana to the Nile system via the Pibor and Sobat Rivers (Nyamweru, 1989).

Artificial wetlands

These owe their existence to human activity which generally changes the topography to create a permanent or seasonal body of water. All over Kenya there are small reservoirs and fish ponds, created by the enlargement of a small natural depression or by the building of a low wall or dam to hold up the flow of water along a drainage line. Larger dams include the Sasumua Dam which provides part of Nairobi's water supply and the dams that have been built during the development of the hydro-electric power resources of the River Tana (Masinga, Kamburu, Gitaru and Kindaruma). At present a new artificial wetland, the Turkwell Gorge Lake, is being born.

Rapidly created, such wetlands may also evolve rapidly. Over its few years large volumes of silt have been deposited in Lake Masinga (the highest and largest of the Tana reservoirs) and unless the rate of soil erosion on its catchment is reduced, this body of open water may change into a silty floodplain within a few decades.

Montane peat bogs

Montane peat bogs are rainfed wetlands which owe part of their existence to the very low rates of evaporation and decay of organic matter at high altitudes. On Mount Kenya the 'Vertical Bog' lies on a rather steep slope, though larger bogs may form within shallow depressions or glacial troughs.

Conclusion

Although Kenya has a great variety of wetlands they are not distributed evenly over the country. As would be expected, most of them occur within the well-watered parts of the country; the coast, highlands and Lake Victoria basin. The extensive plateau lands of Kenya are poorly supplied with wetlands, for both topographic and climatic reasons. Many of Kenya's wetlands are highly vulnerable to changes in the input of water and silt from the surrounding catchments and there is a need to monitor such changes very carefully.

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The hydrology and function of wetlands

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Summary

Wetlands have witnessed increased pressure for development due to the need to produce more food, provide employment and to settle a rapidly growing population. Thus there is an urgent need to investigate the hydrological functions of wetlands in order to develop such areas in a sustainable manner. Wetlands act as runoff regulators, sinks for societal wastes and pollutants, silt traps and rechargers of ground water storage. At present there is little quantitative data which relates wetlands to stream flow, ground water recharge and purification of wastes; examples drawn from Yala Swamp, Lake Amboseli, Lake Ol Bolossat and Lorian Swamp point to the need to investigate and assemble baseline data in wetland areas. The temptation to develop wetland areas without further studies on their impact on the hydrological cycle must be avoided.

Introduction

Wetlands are areas with standing or slowly moving water in the non-capillary pores of the upper layers of the soil, combined with vegetation-covered land that is over-saturated with water, either temporarily or permanently. Seasonal and permanent wetlands cover considerable areas of Kenya. The conditions which predispose an area to wetland formation include:

1. flat relief and impermeable soils or rock close to the surface;
2. clearance or absence of forest cover with the water table situated close to the surface (i.e. dambos);
3. a wide drainage basin which contributes water during the rainy season;
4. accumulation of aquatic vegetation on streams or lakes to impede water flow;
5. margins of river valleys or coastal regions where the ground water aquifer is incapable of storing all the ground water recharge.

Although wetlands may have high rates of evapotranspiration, due to the high ratio of surface area to water depth, they exert a major influence on the hydrologic cycle. Because of high evapotranspiration rates, their surface area fluctuates from year to year and from season to season. There may be water throughout the year in the central core of the wetland. However, as one moves to the periphery, seasonality becomes very obvious.

The study and analysis of the quantity and quality of water on and below the surface of the land is called hydrology. The subject concentrates on the aspect of the hydrological cycle that involves the processes of infiltration, evapotranspiration, soil moisture and ground water storage. The relative importance of each component of the cycle depends on the characteristics of the climate and the drainage basin.

The hydrological cycle

The movement of water through the hydrological cycle, as shown in Figure 1, involves numerous interactions between water and the different environments through which it moves. When rain falls on land a portion of the moisture is intercepted by vegetation and evaporates from temporary storage on leaves. The moisture that reaches the ground either infiltrates the soil, runs off across the surface or evaporates from storage in pockets and depressions. Some of the water which infiltrates the soil is stored as soil moisture, while a portion percolates deeper into the ground and enters ground water storage. The flow of rivers is maintained both by direct surface runoff and by underground flow.

Water recharge in wetlands

Freshwater wetlands are recharged from various sources. Ordinarily, recharge is from rainfall that occurs on the surface of the area but, in some cases, springs and rivers may be the main source of recharge. The rate of recharge depends on the rainfall, soils and topographic characteristics. Rainfall distribution depends on the position of the Intertropical Convergence Zone and the relief of the country. The water retained within the wetland depends on its size, its geomorphological characteristics and its ecosystem dynamics.

Infiltration is one of the most important processes in wetland formation and sustainability. Amongst the local factors that influence infiltration process, rock and soil types are probably the most important as they influence the hydrology of the drainage basin. Soils have both static influences, derived from their water-holding capacity, and dynamic influences associated with water transmission and sedimentation. One of the major static influences is the rate of water infiltration. Soil types in wetlands will generally be clay-loam to silty-loam in order to retain water (see Table 1).

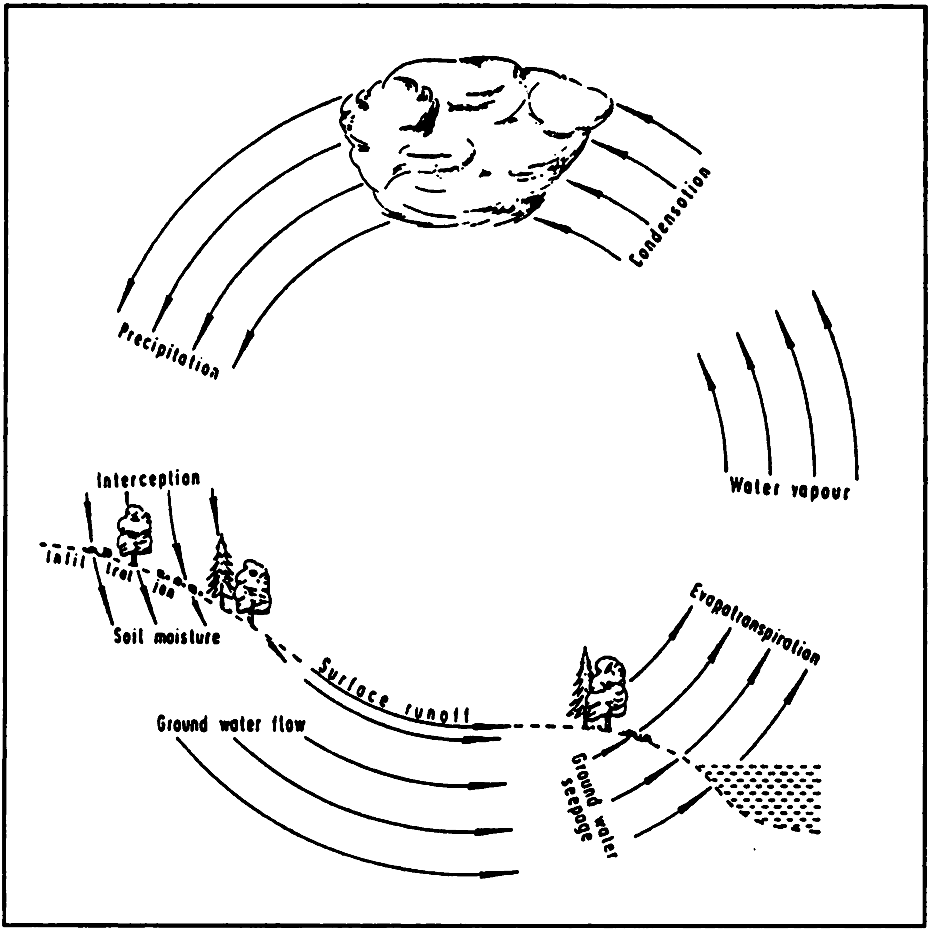

Figure 1 Simplified diagram of the hydrological cycle

Table 1 Infiltration capacities of soil types

Soil type	Infiltration rate (mm/hr)
Clay-loam	2.5 - 5.0
Silt-loam	7.5 - 15.0
Loam	12.5 - 25.0
Loamy-sand	25.0 - 50.0

Whenever the infiltration capacity is reached the downward movement of water stops, causing surface retention and runoff. Because the soils of wetlands are generally clay-loamy, the infiltration capacity is low and a large amount of water is retained on the surface. This water contributes to storm runoff. Infiltration rate also depends on the slope of the land and vegetation cover as well as rainfall intensity and duration.

Discharge of headwater into rivers

Discharge of water into rivers is a combination of overland flow (surface runoff) and base flow from the contributing areas.

The base flow is water which infiltrated the basin and is released from saturated zones of the basin. In forested watersheds the contribution of overland flow to storm discharge is negligible; the base flow is also very small, yet after a storm rivers still tend to increase their volume. These storm discharges are from saturated zones within the drainage basin, including freshwater wetlands.

When comparing river discharge in two basins, one with and one without wetlands, the discharge is less peaked and has a longer duration in the former basin.

Recharge to ground water storage

Wetlands may also function as temporary storages where the velocity of overland flow decreases and infiltration capacity increases. This phenomenon is most common in headwater wetlands. The recharge to ground water storage occurs during floods when water spreads over a large area and increases the wetting surface over which infiltration can occur. This natural practice has now been adopted to artificially recharge ground water in many parts of the world.

The Amboseli Swamp recharges the shallow wells that have been dug around it, however, the magnitude of such recharge is not known. The presence of shallow water is shown by luxurious vegetation in the periphery of the wetland.

Water losses

The main method through which most water is lost from wetlands is through the combined processes of evaporation and transpiration, jointly referred to as evapotranspiration. The amount of water that is likely to be lost from a water body is called potential evapotranspiration while the actual amount of water lost, supply and transmission through plants and soil being limiting factors, is called actual evapotranspiration.

The rate of potential evapotranspiration generally varies with temperature, distance from the coast, wind velocity, atmospheric pressure (altitude) and the nature of the surface. Other factors being constant, the rate of actual evapotranspiration in wetlands will depend on the vegetation cover, the seasonal variation of the wetland size, inflow and outflow of water and the soil particles constituting the wetland bed during the dry season.

In perennial wetlands, the rate of potential evapotranspiration varies with weather patterns because water supply is not a limiting factor. In seasonal wetlands, the rate of actual evapotranspiration varies with the availability of water and its transmission to the surface, either by plants or through the soil structure.

The rate of evapotranspiration depends on the rate of inflow into the wetland area (Shahin, 1971). It is also influenced by the vegetation cover; for instance papyrus and water hyacinth evapotranspire more water than from open surface water. Total evaporation varies with the proportion of free water and vegetated area.

Large quantities of water are lost through the capillary action of the bed deposits. The capillary rise increases with decreasing particle size, thus evaporation is influenced by particle size and depth of the water table (Hellwig, 1974).

While evidence of recharge is easy to obtain, the amount of water loss due to water spreading can be considerable. Nearly 80-98% of the water is lost to evaporation in many parts of the semi-arid and arid tropical areas.

Regulation of river discharges

Wetlands may be responsible for regulating the storm flows of many rivers. As the percentage area of wetlands increases the volume of runoff decreases independently of the mean annual rainfall (Balek, 1983). However, the presence of swamps may decrease runoff by runoff regulation or loss due to high evapotranspiration. The regulatory nature of stream flow by wetlands may result from many causes. A decrease in storm runoff may be caused by the slope of the wetland, such that velocity of runoff is reduced and infiltration increased. Increased infiltration results in more water being stored. During the dry seasons, subsurface flow from saturated wetlands will replenish the flow of dominant streams, thus increasing dry season flow.

The regulatory impact of the wetlands may be assessed by examining the flow duration curves of Kenyan streams. Most of the rivers have a flow duration of two to three months and it is only in the Lake Victoria basin where one finds a flow duration of 8-9 months. The major wetlands on the Lake Victoria drainage basin are situated in the high rainfall western highlands. Because rainfall is ample (more than 1,500 mm/year) and the rate of evapotranspiration is low (1,400 mm/year), such wetlands regulate the flow of the rivers in the basin. However, many wetlands are situated in marginal rainfall areas of northern, eastern and southern Kenya. In other words, water shortage is a characteristic feature of many Kenyan wetlands.

The Ewaso Ngiro (north) basin derives most of its waters from the Nyandarua Range and Mount Kenya. The major tributaries are Ewaso Narok and Ewaso

Ngiro. The mean rainfall distribution increases, with altitude, from less than 250 mm/year near Habaswein to more than 1,500 mm/year near Mount Kenya. The reverse is true of potential evaporation rates which increase from 1,500 mm/year in the highlands (Ol Joro Orok) to a maximum value of 2,600 mm/year at Habaswein and the Lorian Swamp.

The Ewaso Narok system consists of Rivers Ewaso Narok, Pesi and Mutura. There are swamps on each of these tributaries namely Ol Bolossat, Ewaso Narok, Pesi and Suguta-Naibor. On the main tributary of Ewaso Ngiro are Rangai-Burgurret and Moyok Swamps. These swamps spread the river flow during floods which encourages infiltration but also facilitates an efficient evaporation process. The surface flow of the River Mutura dries up in one of the swamps; the local people have dug canals to channel the flow from the swamp in order to irrigate farms in the area.

Grundy (1951) observed that the rate of inflow into Melka Heda Swamp was 4.2 m^3/s, while the outflow was only 1.2 m^3/s. Because of such radical decreases in flow, rates of sediment deposition in wetlands is high. Low and medium flows are unable to pass through such wetlands.

Wetlands as silt traps

The morphology and flow regime of wetlands causes sedimentation. This is particularly so of those wetlands where rivers flow into standing water bodies such as lakes, seas and along floodplains. Generally the velocity of the water decreases in wetland areas because of flooding, vegetation or an increase in channel width.

As a result of reclamation of the Yala Swamp, the sediment bars at the river outlet have increased in their extent (Ochumba and Kibaara, 1989). The River Ewaso Ngiro (north), downstream of Melka Heda, has completely filled its channel with sediments, thus causing flooding in the area (Grundy, 1951). The Tana River has shifted its channel in its lower reaches due to siltation (Tana River Development Authority, 1983). Each of these two rivers moves in excess of 7 million tonnes of sediment during floods. The resulting siltation causes river diversion and flooding which affect the economic activities associated with coastal areas and wetlands such as fishing, dry-season grazing and tourism.

Most of the ephemeral streams (lagas), such as Laga Kokani, Laga Galole and Laga Hirmani in Tana River District, end abruptly without any outlet. The accumulation of sand at such sites has made productive aquifers for ground water storage. Headwater headlands, however, are filled with several metres of colloidal peat, sufficient to support the weight of a man, which reduces evaporation and so makes additional water available for ground water recharge.

Pollution control

Wetlands are often used as sinks for wastes and pollutants. They are efficient decomposers and transformers of organic wastes and thus act as biological filters for sewage and other societal wastes. In addition, their anaerobic processes have a high capacity for uptake of phosphorus, pesticides and other pollutants. When the wetland plants are harvested the pollutants are removed from the ecosystem.

Some toxic wastes, such as metals, are non-biodegradable. These generally sink to the bottom of the wetland because of the reduced flow and are buried with accumulating sediments as the swamp decays into a bog. In other words, wetlands are the natural filtration system of the hydrological cycle.

One of the major threats to the Kenyan environment is from pesticides. The levels here are higher compared with other developed countries (Kallquist and Meadows, 1977). Those wetlands with no or limited outlets are especially in danger from persistent toxic chemicals. Increasing and uncontrolled use of pesticides and the reclamation of wetlands will increase contamination of the environment.

Examples of Kenyan wetlands

Ol Bolossat Valley

The Ol Bolossat is an internal drainage basin. Surface runoff from the Nyandarua and Dodori ridge, and springs that flow from the Sattima Escarpment, drain into Ol Bolossat and Wellmount Swamps. The swamps have high salt content, possibly because of the high evaporation rate and partly due to the nature of the sediments that constitute the area.

Ol Bolossat Valley plays a very important role in containing the excess water from the Ewaso Narok system during the wet season, while during the dry seasons the underground aquifers tend to feed the springs (Figure 2). Some of the excess water infiltrates through fractures and also through the weathered overburden. Boreholes along the valley are relatively shallow, the average depth being about 10 m with a yield of 330 litres/min. Yields of the aquifers, however, tend to vary with the permeability of the rocks and the distribution of fractures. The average yield in fractured zones is 100 litres/min at a depth of 170 m.

The faulted zone to the west of the Ol Bolossat valley acts as a channel for feeding springs in the mid-catchment, thus adding to the volume of the flow in River Ewaso Ngiro. But waters of Ol Bolossat Swamp valley drain northwards and feed Ewaso Narok River thus supplementing its flow.

In summary, the Ol Bolossat Swamp retains flood waters during the wet season and recharges the springs, which in turn feed the main river.

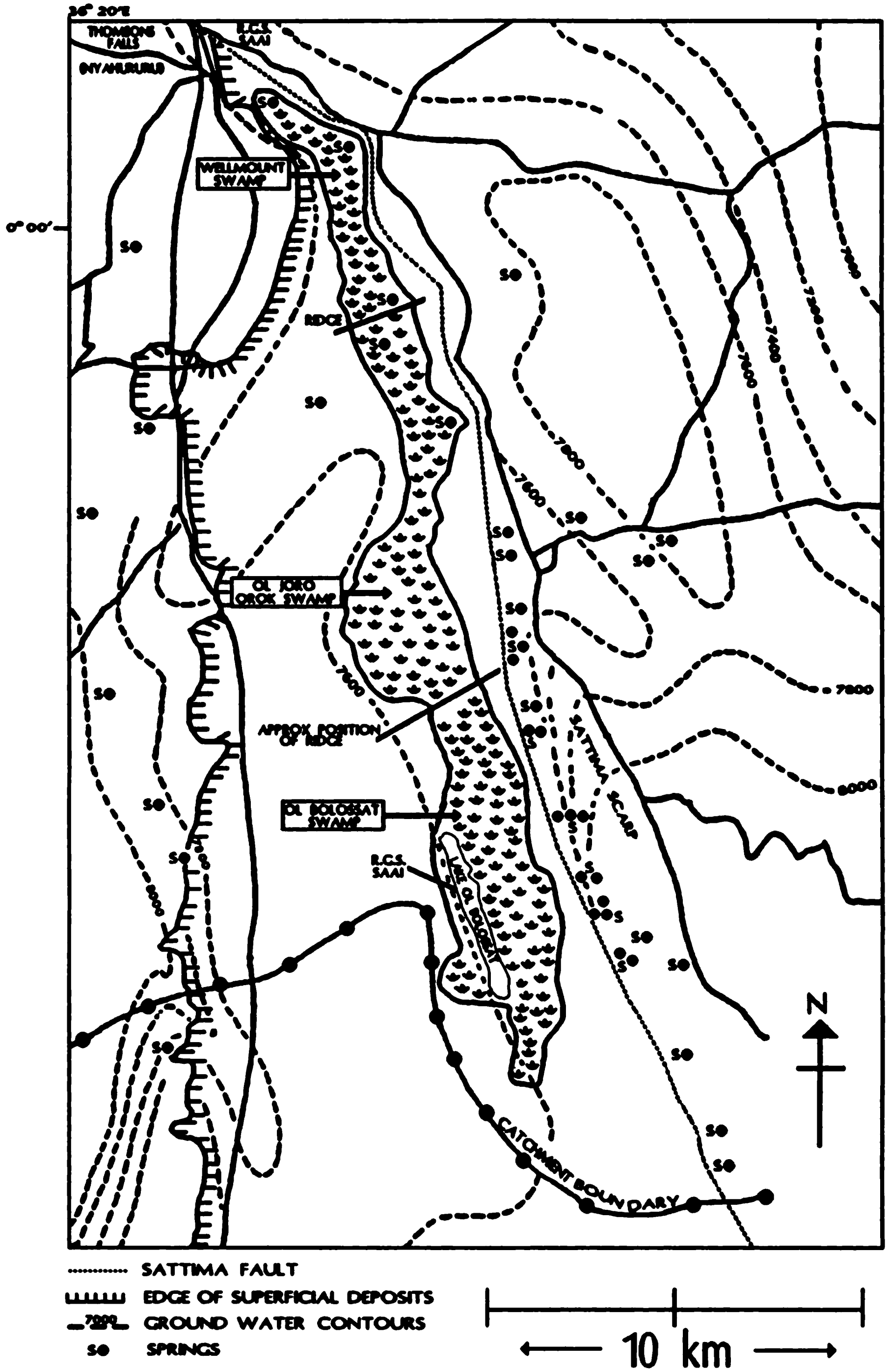

Figure 2 Springs in Ol Bolossat Swamp

Lorian Swamp

The Lorian Swamp is situated in the lower catchment of the north Ewaso Ngiro basin and is less than 300 m above sea level. Its size varies from nil, during drought periods, to a large expanse of water during the wet season. Evidence indicates that the area of the permanent swamp has shrunk from 150 km^2 in 1913 (Haywood, 1913) to about 39 km^2 in 1960 (Government of Kenya, 1962) and 8 km^2 today (Krhoda, 1990).

Conclusion

The concept of biosphere reserves provides both conservation and development frameworks under which a management plan may be established. The rationale for such an integrated plan is to provide support for the local inhabitants, as well as preserve the environment from deterioration. The wetland area is valuable for educational purposes and for preserving genetic resources. The temptation to develop these wetland areas without further investigation should be avoided.

Further research is needed in order to determine the ground water potential of such areas and also to evolve management techniques that would be environmentally sustainable and politically acceptable, since considerable ground water flow of Ewaso Ngiro (north) forms a part of the international ground water resource of both Kenya and Somalia.

The impact of wetlands on regulating stream flow, influencing the rate of siltation of natural reservoirs and in pollution control, is not well established. Studies on selected river basins are required in order to furnish empirical data from which general conclusions may be drawn. As conflicts in land usage and intensity increase, it is expected that pressure will be put on the wetlands of Kenya. Present trends in reclamation supports this view.

During wet periods, excess waters of the basin flood the wetlands and some infiltrate into the ground to recharge ground water reserves. Unfortunately, during the dry seasons, the swamp exposes a large surface area and thus heavy evaporative losses can occur. Because the swamp is underlain by an impervious clay it is possible that, with the high evaporation rate that is experienced in some areas, nearly all water reaching the area is lost. The wells in the swamp and nearby areas are recharged by surface flow rather than from ground water flow.

The hydrological functions of wetlands in Kenya are not well known, however, it is known that the physical and biological characteristics of wetlands will influence the parameters of the hydrological cycle such as water storage, infiltration, evapotranspiration and runoff. Similarly, wetlands constitute the natural purifying process of water within the hydrological cycle.

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An account of some important freshwater wetlands of Kenya

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Summary

Freshwater and other upland wetlands of Kenya are classified and noted for their importance for conservation and productivity. Major riverine wetlands and shallow waterbody wetlands are described and a detailed analysis is given of the structure, biology, limnology, vegetation and fisheries of the floodplain wetlands and associated lakes. The Tana Delta and Yala Swamp wetlands are analysed in detail and the Lake Naivasha wetland described.

Introduction

Wetlands are some of the most important and threatened ecosystems throughout the world. They are prime targets for exploitation, modification and destruction by human activities such as drainage, reclamation, pollution and biological alteration through biotic introductions. Advantages of wetland conservation have been highlighted by international bodies such as IUCN, UNEP and WWF (IUCN *et al.*, 1980) and recently by the Ramsar Convention Bureau (1988).

Wetland ecosystems in Kenya are diverse and important natural resources which include areas of ecological importance and conservation value both nationally and internationally. They are vital components of the hydrological cycle and are essential breeding, rearing and feeding habitats for many species of fish, waterfowl and other wildlife. Kenyan wetlands are exploited on both seasonal and long-term sustained basis through grazing, direct harvesting of plant material and fishing. They provide opportunities for recreation and tourism and are major water resources for industrial, domestic, livestock and agricultural uses.

Most natural wetland ecosystems in Kenya, and other tropical countries, are threatened by hydrological, agricultural and other human activities (Mavuti, 1989). Increasing national and international recognition of the values of wetlands has intensified the need for reliable information on the status and extent of these natural resources. However, most research efforts have been centred on wetlands in temperate regions and only recently has research begun on the basic structure and function of the African wetlands (Gaudet, 1976, 1977a and b, 1978, 1979; Mavuti, 1989).

In contrast to the considerable amount of basic research and interest that has been focused on terrestrial ecosystems in Kenya, comparatively little is known about the characteristics and ecology of Kenyan wetlands. The need for thorough appraisal and synthesis of research on the ecology, limnology and dynamics of Kenyan wetlands is long overdue. The fast growing population has increased the demand for agricultural land, particularly through swamp drainage and reclamation.

Distribution and characteristics of wetlands in Kenya

Wetlands have usually been defined according to purpose (Cowardin *et al.*, 1979). There is a need to understand and describe the characteristics and values of these areas for wise management.

In general, wetlands may be regarded as areas of land where there is alternate seasonal flooding and the water table remains at or near the surface or land which is permanently covered with shallow water; where light penetrates to the bottom and with characteristic hydrophytes. According to Dugan (1990) the term 'wetland' groups together a wide range of inland, freshwater, coastal and marine habitats that override climate and which share common features. The Ramsar Convention definition of wetlands is found in the Preface to this volume.

Wetlands in Kenya are recognised as falling under one or more of the following categories (Mavuti, 1981):

1. Permanent reed marshes and grassy swamps with characteristic hydrophytes and hydric soils.
2. Hydric soil flats devoid of hydrophytes due to either drastic fluctuations in water level, high concentrations of salts or a combination of both.
3. Littoral areas of lakes with either floating or rooted fringing vegetation and deltaic swamps, including the drawdown area of the lake shores.
4. Permanent freshwater or saline shallow lakes and ponds that are not more than four metres in depth where light penetrates to the bottom.
5. Seasonal swamps, marshes, ponds and other temporary water bodies that persist long enough to develop hydrophytic floral and faunal complexes.
6. Margins of impoundments and reservoirs where hydrophytes have become established but hydric soils have not developed.
7. Seasonal and river floodplains and their associated lakes.
8. Agricultural wetlands resulting from irrigation, including rice fields and reclaimed natural swamps.

Wetlands in Kenya may be riparian (developing in the mid-courses of rivers), riverine (due to impeded drainage in valley bottoms) or deltaic (forming at the mouth of large rivers discharging into lakes, seasonal ponds or pools). The distribution of major natural aquatic systems and freshwater wetlands in Kenya is shown in Figure 1.

In the following account, several important riverine, floodplain and lacustrine wetlands will be discussed in some detail to describe their characteristics and to highlight gaps in our current knowledge of these important freshwater resources.

Riverine wetlands

A majority of the rivers in Kenya are seasonal, intermittent and form insignificant floodplains as they flow within gullies. However, important floodplains are developed on the major rivers. The type of hydrophytes that develop in these areas depend mainly on the salinity of the water, soil type and the gradient of the land at the river course.

Of particular interest are the freshwater Lorian Swamps, where conductivity is less than 600 µS/cm, at the terminus of the Ewaso Ngiro (north) River at Derra. The Lorian Swamps are some of the most crucial riverine wetlands because they exist in an arid zone where annual rainfall is usually below 200 mm/year. Because of hostile terrain and insecurity in this area, little is known about these swamps. On the upper courses of the river are found some extensive floodplain swamps called the Ewaso Narok.

On the headwaters of the Tsavo River are found the luxuriant Lengurruahange Swamps which may be considered to be an extension of the Amboseli wetlands. The freshness of these swamps (less than 300 µS/cm) is important as it allows a wide variety of plants, waterfowl and aquatic fauna to thrive.

Moderately saline grass swamps (conductivity 600-1,000 µS/cm) are usually found in the dry Rift Valley regions in Kenya. Over 30% of the country drains into interior basins in the Gregory Rift Valley region where most of the shallow lakes have no outlet. Along the lowland courses of the rivers flowing into these lake basins, lotic and lentic swamps and marshes have developed. Because of the volcanic nature of the basement rock on which they exist, their waters are usually sodic with sodium bicarbonate as the principal solute. They do not support large hydrophytes except a few species of *Carex* and *Typha*, but have developed characteristic hydric soils with grasses and sedges that are well adapted to high salinity, in particular *Cyperus laevigatus* and *Schoenoplectus confusus*.

Good examples of such swamps in Kenya are the Loboi Swamp on the Bogoria River, the Kisibar Swamp on the Waseges-Sondai River, Ol Matashu Swamp on the Molo River, Ol Bolossat Swamp on Simba and Dundori Rivers and Olobanita Swamp north of Lake Nakuru. Virtually nothing is known about the ecology of these grass swamps.

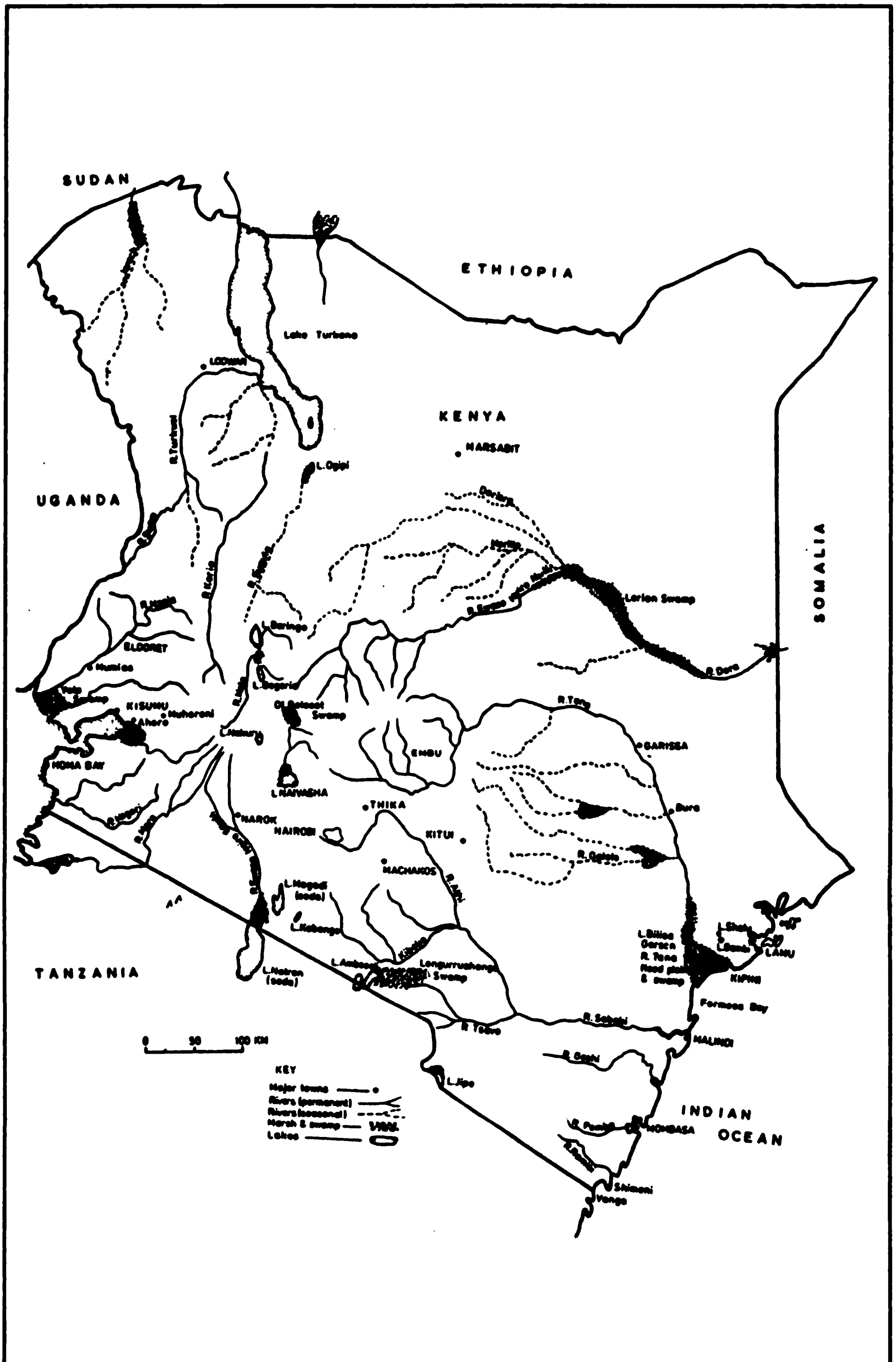

Figure 1 The major aquatic systems in Kenya
(drawn from Survey of Kenya map, Series SK 72/1978)

Shallow waterbodies, ponds and seasonal pools

Temporary pools appear during the rains in shallow basins, depressions, excavations and flood areas all over Kenya and elsewhere in East Africa (Cloudsley-Thompson, 1969). They are common all over Kenya during the rainy season. Although most of these water bodies are temporary, and therefore do not have enough time to develop characteristic hydrosoils and hydrophytes, they are essential wetlands for various animals and plants. Some ponds may persist for a long time and may develop characteristic wetland flora and fauna, such as the Athi Plain pools on the Nairobi-Kangundo road.

Most of these water bodies contain a wide variety of plant and animal species; they are used by wildlife and cattle, especially in the dry seasons, and as a water resource by the local people.

These temporary standing waters may persist for as long as six months and may develop characteristic biotypes. Their fauna is dominated by a few cladocerans (*Daphnia* and *Moina)*, copepods (*Tropodiaptomus, Thermodiaptomus* and *Thermocyclops*) and rotifers (*Brachionus, Keratella*). The filter feeding notostracan (*Triops* spp.) and anostracans are rarely found. The life span of these animals in the temporary waters is very short and their existence is a race against time for they must reach maturity and reproduce before the pools dry up.

Floodplains and associated lakes

The best example of floodplain wetlands is found on the Tana River delta, below Garsen, where an expansive wetland mosaic has developed. The Sabaki River has a significant floodplain while other floodplain lakes, Kanyaboli, Nambogo and Sare, are found on the Yala Swamp (Mavuti, 1989).

Tana Delta wetlands

The Tana River has changed its course to the Indian Ocean many times; with the changes in the river channels, numerous oxbow lakes develop such as Lakes Pongi, Bilisa, Giritu, Shakababo, Dida Warede, Moa and Harakisha.

Lake Bilisa is located just to the north of Garsen in an expansive wetland dominated by emergent, floating and submerged macrophytes. The lake has flowing water originating from the diversion at Mnazini. The dominant emergent plant species include aquatic grasses (*Echinochloa haploclada*) and sedges (*Cyperus frerei*, *C. heterophylla* and *C. tuberosus*) while floating macrophytes include the Nile cabbage (*Pistia stratiotes*), and *Lemna* spp.; *Ceratophyllum demersum* is the dominant submerged aquatic species. There is abundant birdlife and a variety of fish species. The aquatic grasses are harvested as fodder for milk cows and calves, while sedges are used for thatching (Government of Kenya (GOK), 1991).

Lake Shakababo is located west of the Tana River near Ngao. Water from the Tana River enters from two sources via the Kisichi Canal and through Lake Kongolola. There is marked zonation of the wetland grasses; *Echinochloa haplocada* is found closest to the water and *Bothriochloa bladhii* and *Panicum maximum* are found at increasing distances towards the *Acacia robusta/Terminalia spinosa* woodland.

Various species of fish inhabit the lake, including *Sarotherodon mossambicus, Synodontis zambesiensis, Mormyrus* sp., *Clarias mossambicus, Labeo gregorii, Protopterus amphibius* and *Anguilla mossambicus* (GOK, 1991).

Dida Warede Lake is an expansive, grass-covered wetland with scattered open water patches. In the open water, profuse growths of aquatic plants are dominated by Nile cabbage *(Pistia stratiotes)*, the water lily (*Nymphaea lotus*) and the aquatic fern (*Azolla nilotica*). Waterfowl are abundant and include the African Jacana, Grey Heron and Sacred Ibis. The bushland vegetation along the southern shore is a breeding ground for herons and ibises. The lake is utilised as a dry season grazing area by the local Orma people and a fishing ground by Luos and Luhyas (GOK, 1991).

Lake Harakisha is rich in waterfowl and is a breeding ground for large numbers of water birds which concentrate there towards the end of the flood season (S. Njuguna, pers. comm.). The lake is usually covered by the wetland grasses *Echinochloa haploclada* and *Bothriochloa bladhii.* Like Lake Warede, it serves as an Orma dry season grazing area with small-scale fishing activities.

The Sabaki River

The Sabaki River forms a very important floodplain at its lower course near Malindi (Mavuti, 1981). In the last 80 km, the river falls 100 m and forms a broad floodplain in which permanent and temporary lakes are common (Whitehead, 1960).

The floodplains of the Sabaki River and the deltaic swamps of the Tana River provide water and fishery resources for the local people. There are subsistence fisheries on the lower reaches of these rivers operated by the Orma and Giriama people on the lower Sabaki River and the Pokomo people on the Tana River. Lungfish (*Protopterus* spp.) and catfish (*Clarias* spp.) are the largest fish of the Sabaki with the latter reaching 5-10 kg in weight. Two cichlid species *Sarotherodon mossambicus* and *S. spirulus nigra* also occur on the lower Sabaki and reach 2 kg in weight; a variety of other smaller fishes that occur in the oxbow lakes are described by Whitehead (1960).

Freshwater prawns are also abundant in the lower Sabaki and make a valuable contribution to the local fishery. The main species are *Macrobranchium lepidactylus*, which reaches 40 g in weight, *M. rude* and *M. scabrinsculum*. Originally from Lake Victoria, *Caridina nilotica* and *C. africana* are found in the Sabaki River floodplains and lakes.

Despite this rich piscine fauna of local commercial importance, little or no limnological work has been undertaken on these rivers due to difficulties of access and funding.

Yala Swamp and lakes

Freshwater, deltaic wetlands occur at the mouths of major rivers as they discharge into lakes. Usually they are formed as a result of backflow of water from the lakes into the river channels. The resulting sedimentation blocks the river mouth and causes further accumulation of alluvium. This has been the case on the Yala River in Siaya District, where an expanse of swamp land has formed in the northeast of Lake Victoria (Figure 2).

The Yala Swamp covers an area of about 17 km^2; reclamation began in 1956 but there is controversy regarding further reclamation. Areas of high ground within the swamp are inhabited by people of the Bunyala tribe, on the northern side, and by people of the Luo tribe in the southern regions.

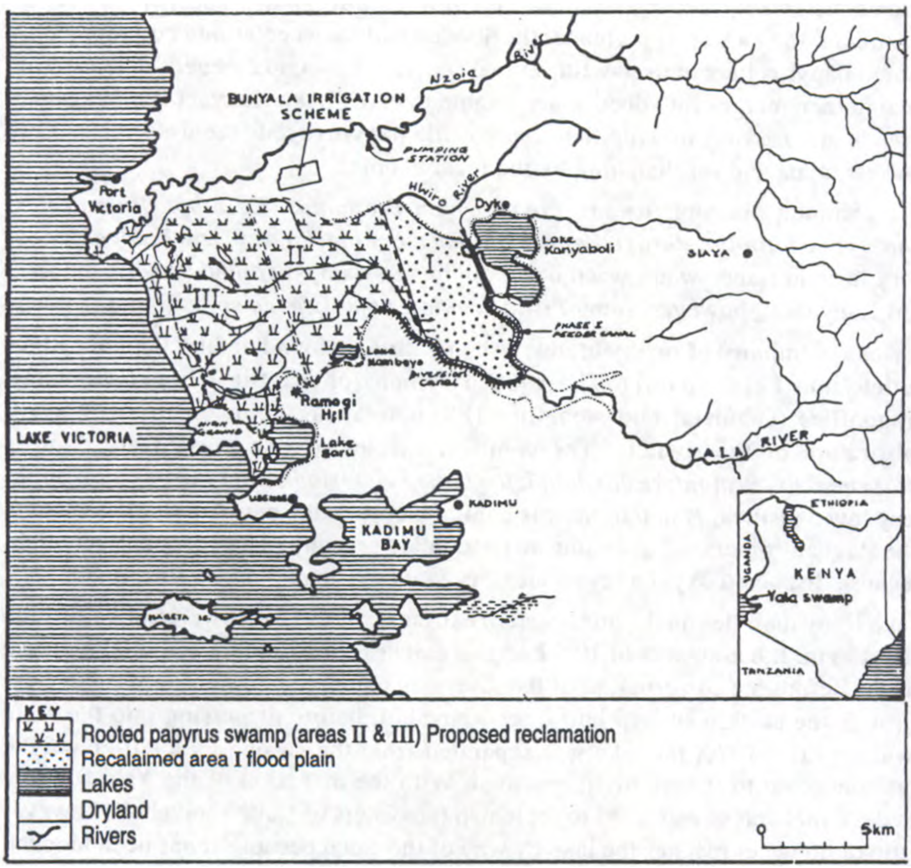

Figure 2 Geographical layout of the Yala Swamp and associated lakes

The Yala Swamp is an important ecosystem for various species of birds and mammals. It acts as a natural filter for a variety of biocides and other agricultural pollutants from the catchment (Mavuti, 1989). The Yala Swamp lakes (Figure 2) have been described by Mavuti (1989). The water discharging into Lake Victoria through the swamp is of good quality; visually it is very clear with little appreciable colour. Although the chemistry of the water is not significantly different from that of the main river, its physical clarity is due to the filtering effect of the swamp into which most of the sediment load is deposited before the water enters the lake. The water in the channels is also well oxygenated (8 mg O_2/litre) with conductivities of between 100-120 μS/cm.

The rooted vegetation of the Yala Swamp is primarily *Cyperus papyrus*, in most inundated places, and *Phragmites mauritianus* on the drier and higher ground. The shore is lined with a wide belt of *C. papyrus* and swamp grasses, while further inland the swamp becomes a dense mixture of *Phragmites* and papyrus reeds. Upstream, the swamp is permanently flooded and the vegetation is dominated by rooted papyrus interspersed with several species of swamp creepers. The papyrus swamp then merges into deep water swamp towards Lake Kanyaboli. *Phragmites* strands are used for making fish traps, while papyrus reeds are used for making baskets, mats and for thatching by the local people.

The common macrophytes are *Potamogeton pectinatus, Ceratophyllum demersum, Typha latifolia, Phragmites mauritianus, Echinochloa* sp. and *Polygonum* sp. Very little nuisance water weed occurs in these swamps; around Lakes Namboyo and Kanyaboli, however, some *Pistia stratiotes* and *Lemma* sp. is found.

A rich community of invertebrates, fish and birds is found among the Yala River outlets into Lake Victoria. The aquatic nymphs of mayflies (Ephemeroptera), dragonflies (Odonata) and stoneflies (Plecoptera) are common in the gravely substratum of the rivulets. The common species of fish present are *Clarias mossambicus, Protopterus aethiopicus, Labeo victorianus* and *Barbus* spp, but in very low densities; *P. aethiopicus* is common only in the periphery of the swamp. The stagnant waters of the swamp do not contain as many fish as originally thought because dissolved oxygen levels are very low (less than 4 mg O_2/litre).

Lake Kanyaboli lies on the northeastern extremity of the Yala Swamp at an altitude of 1,156 m. It has an area of 10.5 km^2 and reaches a maximum depth of 3 m in the north. Before the construction of the diversion canal, the Yala River used to flow through the eastern swamp into Lake Kanyaboli before dispersing into the main swamp. After 1970, the lake was separated from the swamp by a silt-clay dyke but connected to it by a drainage canal. With the diversion of the Yala River, a feeder canal was constructed to replenish the waters of Lake Kanyaboli, however little or no water reaches the lake by way of the canal because it has been blocked and damaged by livestock. The main source of water for the lake is from the immediate catchment area west of Siaya town and by back seepage from the swamp.

The physico-chemical properties of Lake Kanyaboli water, compared with other lakes within the swamp, have changed drastically (Mavuti, 1989); the salinity has more than doubled in less than 15 years. Since the diversion of the Yala River and the construction of the protection dyke, the salinity of the lake has gradually increased due to lack of water replenishment from the river. Had the feeder canal been maintained in functional condition, perhaps this increase in salinity would not have occurred.

Like Lake Sare, Lake Kanyaboli is surrounded by a thick papyrus swamp with a few floating papyrus islands. The major phytoplankton groups are blue-green algae and a few green algae; the zooplankton community is represented by copepods (*Thermocyclops* spp.), a few cladocerans and rotifers (*Brachionus* spp.). The plankton community is poorer than that found in Lake Victoria and possibly has changed due to progressive salinisation.

The indigenous fish *Oreochromis esculentus* and *O. variabilis*, which formed the mainstay of the tilapia fishery in Lake Victoria in the 1950s and 1960s, but are now absent, are only found in appreciable numbers in Lake Kanyaboli. Lake Kanyaboli was found to have a richer fish community than Lake Sare and is a very important nursery and refuge area for *Protopterus aethiopicus* and *Clarias mossambicus*. These fishes form the basis of subsistence fisheries in both Lakes Kanyaboli and Sare. In 1981, Lake Kanyaboli produced about 250 tonnes of fish composed of approximately 50% *O. esculentus* and 40% *O. niloticus*. It is therefore imperative that proper management be maintained to protect this fishery from the voracious Nile Perch. The fish community of Lake Kanyaboli is therefore unique as it is a living museum of that of pre-1960 Lake Victoria.

Lake Sare is part of the southern outlet of the Yala River into Lake Victoria. Before the construction of the culvert it was but a gulf of Lake Victoria; its separation meant that it was no longer influenced by the waters of Lake Victoria. The culvert across the mouth of the Yala River on the southern outlet is 1-2 m above the normal level of Lake Victoria, thus the backwaters of Lake Sare have flooded and drowned the surrounding land. Lake Sare itself is about 5 km^2 in area and 5 m deep at its centre. The lake is surrounded by a fringing papyrus swamp which merges with the main swamp.

The physical, chemical and ecological characteristics of Lake Sare are influenced by the flow of the Yala River. The water chemistry of this lake is similar to that of the adjacent swamp. Before the water reaches Lake Sare, it has passed through the filtering systems of the swamp and therefore contains very little nutrient and suspended matter. Dissolved solids chelate out in the swamp environment and are filtered out by the papyrus. The conductivity of Lake Sare water is 120-130 $\mu S/cm$ with a pH of 7.6. The water is well oxygenated, between 7 and 9 mg O_2/litre during the day. The bottom zone is mulched with detritus of papyrus with little soil or gravel substratum. Burrowing nematodes, mayfly nymphs, dragonfly nymphs and the swamp Oligochaetes (*Alma emini* and *Limnodrilus* sp.) dominate.

Limnologically the lake is relatively unproductive. The free water column contains very little phytoplankton and zooplankton; a few specimens of *Melosira* sp., *Microcystis* sp., *Navicula* sp. and cyclopoid copepods are found in very low densities (less than 2 individuals/litre, compared with Lake Victoria plankton densities of 380 individuals/litre).

The fish fauna is not particularly rich. The most dominant fish species are *Oreochromis niloticus, O. leucostictus* and *Haplochromis* spp. In the fringing swamp are *Propoterus aethiopicus*, *Synodontis victoriae, S. afrofischeri* and *Clarias mossambicus*. Lake Sare is infested with the carnivorous Nile perch (*Lates niloticus*); the absence of *Oreochromis esculentus* and *O. variabilis* from Lake Sare as well as Lake Victoria is the result of the predation pressure by Nile perch, in addition to over-fishing by the local people.

Lake Namboya is very small (1 ha) but is 10-15 m deep and lies on the southern extremity of the swamp (Figure 2). The surrounding Nyando-Ahero Swamp is highly polluted with domestic sewage from Kisumu town and agricultural pollutants from the sugar and rice schemes in Ahero. This swamp filters these pollutants from water entering Lake Victoria. The lake is surrounded by rooted as well as floating papyrus. Except as a source of water for the local people and livestock, relatively little use is made of this lake. Conductivity comparisons indicate that there is little mixing of water between Lake Namboyo and the main swamp.

Shallow lakes and their littoral swamps

Low salinity (less than 500 µS/cm) freshwater lakes and swamps are mainly littoral swamps dominated by *Cyperus papyrus*. Lakes Victoria and Naivasha are relatively 'sweet' freshwater lakes (180-350 µS/cm) and have extensive areas of floating and fringing papyrus and littoral swamps which provide varied habitats for a diverse fauna. The lakes' water is used for domestic purposes, irrigation and sewage disposal for the adjacent towns.

Lake Naivasha north swamp is the most well-studied papyrus swamp in the country (Gaudet 1976 and 1979). Water entering the lake from the Malewa, Gilgil and Karati Rivers passes through the north swamp into the lake. This swamp is virtually a monoculture of *Cyperus papyrus*; its structure and function has been described (Gaudet, 1978 and 1979; Howard-Williams and Gaudet, 1979). The effect of this swamp on the chemistry of the water entering the main lake have been studied by Gaudet (1979). However, the subject of nutrient budgets and recycling in the lake is still unknown, as is the case for the other shallow lakes in Kenya.

The vegetation around the main part of Lake Naivasha consists of a papyrus fringe; sedges and grasses are found in regions where papyrus has been cleared and on the drawdown zone which is exposed during periods of low water level. Along the edges of Oloidien Lake the more alkaline soils support a flora common to the soda lakes, dominated by the salt tolerant *Cyperus laevigatus*. The formation of the lagoons and papyrus reefs were discussed by Elder *et al.* (1971) and their general ecology by Gaudet (1977a).

Many vertebrate animals are found in the Lake Naivasha swamps. These include the hippopotamus, reedbuck and introduced coypu. The humid atmosphere of the papyrus provides an excellent environment for the semi-aquatic insects which are the food of the swamp snakes and chameleons (Gaudet, 1976). The avifauna includes many species of water fowl including coots, ibises, cormorants, pelicans, storks, spoonbills, ducks and geese.

Under tropical conditions, swamps support a comparatively poor fauna and flora of truly aquatic forms due to the low oxygen content in swamp water and to shade. However, Lake Naivasha swamp water contains comparatively high concentrations of dissolved oxygen (3.0-6.0 mg O_2/litre) and consequently the swamp maintains abundant aquatic flora and fauna. The plankton is rich with blue-green and green algae (*Microcystis, Lyngbya, Oscillatoria, Melosira* and *Synedra*).

Crustaceans and rotifers are important components of both the swamp and limnetic zooplankton of Lake Naivasha, including *Diaphanosoma, Simocephalus, Thermocyclops, Mesocyclops* and *Brachionus*. Chironomids, together with ostracods, oligochaetes, nematodes, naidid worms, ephemerid larvae and other lake invertebrates form an important component of the lake benthos. Vast numbers of lake flies emerge from the swamps forming huge clouds at dusk. The introduced crayfish *(Procambrus clarkii)* forms an important food item for the introduced largemouth bass (*Micropterus salmoides)*. However, of all the communities in the Lake Naivasha basin, the ecology of the invertebrates is the most poorly documented.

The Lake Naivasha fishery is based on several species introduced in the 1920s and 1960s; *Oreochromis leucostictus, Tilapia zilli* and *Micropterus salmoides*. They are the most favoured freshwater fish in Kenya, after *Barbus* and *Labeo* of Lake Victoria (Siddiqui, 1977 and 1979; Litterick *et al.*, 1979).

Grass swamps and irrigation wetlands

An expanse of mixed papyrus-grass swamp is found on the deltaic plains between the Nzoia and Yala Rivers and on the Kano plains on the Nyando-Sondu River flowing into Lake Victoria. The Yala and Sondu Swamps around Lake Victoria are currently being drained for food production; the Yala Swamp has a reclamation potential of 19,000 ha. By 1980, approximately 380 ha had been drained around the Nzoia River and converted to rice fields. The deltaic grass swamp of the Kano plains (14,000 ha) have had 850 ha reclaimed at Ahero and 900 ha in West Kano; both are under rice and sugar cane. The grass swamps in Kenya are fast being reclaimed and converted into agricultural use and, therefore, few are being conserved as natural wetlands. Many believe that Kenya needs food more than idle natural swamps (Okondo, 1989) and therefore the reclamation of these wetlands into agricultural units seems legitimate and justified.

On the slopes of Mount Kenya several irrigation schemes derive their water from the Thiba River. The major agricultural wetland is the Mwea-Tabere irrigation scheme which has 5,700 ha under rice (Mavuti, 1981).

In the grass swamps and irrigation wetlands, particularly the Mwea and Tabere irrigation schemes, malarial mosquitoes can be a problem. Several species of aquatic snails, of the genera *Bulinus* and *Biomphalaria*, live among the aquatic macrophytes in the irrigation canals and channels. These snails are involved in the transmission of schistosomes (*Schistosoma mansoni, S. haematobium*) to the local population. The control of bilharzia and malaria in the agricultural wetlands is currently being conducted by the National Irrigation Board of Kenya. There is a great aquaculture potential in the irrigation schemes, especially for tilapia and carp; the effect of biocides on the aquaculture fish and invertebrates is being researched (R. Mwangi, pers. comm.).

Conclusion

Swamps and other types of freshwater wetlands in Kenya cover less than 3% of the total surface area of the country. Their conservation does not receive priority on a national scale. However, if a case for conservation is made for a particular swamp or wetland, it could then be legally protected. The tendency in Kenya is to drain, reclaim and convert wetlands into farmlands for food production. In general wetlands in Kenya are biologically very productive environments.

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Wetland birds of Kenya

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Introduction

Kenya has a surface area of 582,645 km^2 and a wide range of climatic conditions. The country has a rich avifauna comprising 1,060 species (Britton, 1980), attributed to the fact that Kenya has diverse terrestrial and water-associated habitats. Kenya also lies at the intersection of the distribution of many afro-tropical species and within the wintering ranges of many Eurasian migrants.

Because of the wide environmental conditions in which birds of different species occur in Kenya, any long-lasting conservation strategy must be based on preserving ecosystems with the greatest biological diversity. Wetlands are particularly important in this regard.

Wetland bird community structure

Of the 1,060 species of birds found in Kenya, some 255 species (composed of 44 families and 56 groups) are associated with water or aquatic vegetation (Table 1). Thus, wetlands support approximately 25% of Kenya's avifauna.

Inland waters support some 235 bird species while the marine (littoral) habitats harbour another 20 species; 88 species are dependent on water while the remainder (167 species) are dependent on aquatic vegetation and water-edge microhabitats.

The water-dependent species account for 33% of Kenya's wetland avifauna (Table 2). The marine avifauna includes a few resident species, some palaearctic migrants and pelagic vagrants which occasionally wander into the coastal areas from the Indian and Antarctic Oceans. The water-dependent avifauna is dominated by ducks, gulls and terns. Over 60% of the families of water-dependent birds contain one or two species. Thus, species richness in true aquatic birds is low.

Of the 170 species not directly dependent on water, 65 are dependent on the water-edge and 105 species depend on emergent aquatic vegetation. The water-edge bird community is dominated by plovers and sand pipers. Birds which depend on

Table 1 Number of Kenyan species of birds associated with water

Family	Typical groups	Number of species
PODICIPEDIDAE*	Grebes	3
DIOMEDEIDAE*	Albatrosses	1
PROCELLARIIDAE*	Petrels, Shearwaters	5
HYDROBATIDAE*	Storm Petrels	3
PHAETHONTIDAE*	Tropicbirds	2
PELECANIDAE	Pelicans	2
SULIDAE*	Boobies	3
PHALACROCORACIDAE	Cormorants	2
ANHINGIDAE	Darters	1
FREGATIDAE*	Frigatebirds	2
ARDEIDAE	Herons, Bitterns, Egrets	18
SCOPIDAE	Hamerkop	1
CICONIIDAE	Storks	8
THRESKIORNITHIDAE	Ibises, Spoonbills	6
PHOENICOPTERIDAE	Flamingos	2
ANATIDAE	Ducks, Geese	24
ACCIPITRIDAE	Birds of Prey	5
PANDIONIDAE	Osprey	1
GRUIDAE	Cranes	2
RALLIDAE	Crakes, Rails	11
HELIORNITHIDAE	Finfoot	1
JACANIDAE	Jacanas	2
ROSTRATULIDAE	Painted Snipes	1
HAEMATOPODIDAE	Oystercatchers	1
CHARADRIIDAE	Plovers	22
SCOLOPACIDAE	Sandpipers, Snipes	31
RECURVIROSTRIDAE	Stilts, Avocets	2
PHALAROPIDAE	Phalaropes	2
DROMADIDAE	Crab Plover	1
BURHINIDAE	Thick-knees	2
GLAREOLIDAE	Coursers, Pratincoles, Egyptian Plover	5
STERCORARIIDAE*	Skuas	4
LARIDAE	Gulls, Terns	25
RHYNCHOPIDAE	Skimmers	1
ALCEDINIDAE	Kingfishers	5

Note: Families marked with an asterisk (*) are coastal and marine

Table 2 Number of Kenyan species of wetland birds which are dependent on water

Family	Typical groups	Number of species
PODICIPEDIDAE	Grebes	3
DIOMEDEIDAE	Albatrosses	1
PROCELLARIIDAE	Petrels, Shearwaters	5
HYDROBATIDAE	Storm Petrels	3
PHAETHONTIDAE	Tropicbirds	2
PELECANIDAE	Pelicans	2
SULIDAE	Boobies	3
PHALACROCORACIDAE	Cormorants	2
ANHINGIDAE	Darters	1
FREGATIDAE	Frigatebirds	2
THRESKIORNITHIDAE	Spoonbills	1
PHOENICOPTERIDAE	Flamingos	2
ANATIDAE	Ducks, Geese	22
ACCIPITRIDAE	Fish Eagle	1
PANDIONIDAE	Osprey	1
RALLIDAE	Coots	1
HELIORNITHIDAE	Finfoot	1
JACANIDAE	Jacanas	2
STERCORARIIDAE	Skuas	4
LARIDAE	Gulls, Terns	24
RHYNCHOPIDAE	Skimmers	1
ALCEDINIDAE	Kingfishers	4

Table 3 Passerine birds associated with aquatic vegetation in Kenya

Family	Typical groups	Number of species
MEROPIDAE	Bee-eaters	2
HIRUNDINIDAE	Swallows, Martins	5
SYLVIIDAE	Swamp Warblers	15
MUSCICAPIDAE	Flycatchers	1
MOTACILLIDAE	Wagtails	4
LANIIDAE	Shrikes	1
PLOCEIDAE	Weavers	17
ESTRILDIDAE	Waxbills	2
FRINGILLIDAE	Swamp Canary	1

emergent aquatic vegetation are herons, storks, cranes and passerine birds; the latter group consists of 48 species in which sylviid warblers and ploceid weavers predominate (Table 3). There are several species such as the Swamp Gonolek (*Laniarius mufumbiri*) and the Papyrus Yellow Warbler *(Chloropeta gracilirostris)* which are endemic to papyrus swamps.

Important wetlands and their birds

Kenyan wetlands can be classified into Indian Ocean littoral, Rift Valley lakes, seasonal lakes and swamps, man-made dams and wetlands and river or valley bottom wetlands. The major sites of ornithological importance within Kenya's main wetland systems are shown in Table 4.

Indian Ocean littoral habitats consist of mangrove forests, coral reefs, tidal creeks, salt pans and tidal flats. These provide a wide range of niches for birds. At the Kenya coast, most of the important ornithological sites are protected within the existing marine national parks and national reserves.

The wetlands of Kenya cover an area of approximately 14,000 km^2 and constitute important habitats for waterfowl. Twenty-one species of ducks (eleven resident and ten palaearctic) and three species of geese (all resident) utilise Kenya's inland wetlands. Some of the sites that are important for waterfowl in Kenya are shown in Table 4.

Mida Creek is situated in a marine national reserve and is an extensive intertidal inlet which is lined by mangrove forests. This is an important wetland for thousands of passage and wintering waders, especially Crab Plovers (*Dromas ardeola*). The Sabaki Estuary, situated north of Malindi, is an important site for passage waders, gulls and terns. It is the most important wintering site for the Broad-billed Sand Piper (*Limicola falcinellus*) but has no conservation status at present. Other important littoral sites are Kilifi and Dodori Creeks. These have protected area status but the Tana River Delta and the Kiunga Creek are within larger sites proposed as marine national reserves.

Along the Great Rift Valley system, there are large (Lake Turkana), intermediate (Lakes Logipi, Kamnarok, Baringo, Bogoria, Nakuru and Magadi) and small (Lakes Elmenteita, Sonachi and Oloidien) alkaline lakes. One of the few freshwater bodies within the Rift Valley is Lake Naivasha. Most of these lakes have high natural productivity and are therefore important sites for waterfowl. However, only a few have a protected area status; such as Lakes Nakuru and Bogoria. Lake Elmenteita's basin is a proposed national reserve (see Table 4). The Rift Valley, with its associated system of lakes, is the main flyway of palaearctic ducks in Kenya (Gichuki, 1991). Most of these migrating ducks stop-over in Rift Valley wetlands during their southward migration. The ducks migrating northwards tend to spread outside the Rift Valley into central and eastern Kenya.

Lake Turkana (7,200 km^2) is moderately saline and is the largest of the Rift Valley lakes. The common resident birds include pelicans, flamingos and herons; these birds also occur in other Rift Valley lakes. Turkana is, however, an important resting site for large numbers of visiting water-edge birds such as the Kentish Plover *(Charadrius alexandrinus)*, Broad-billed Sandpiper (*Limicola falcinelllus*), Long-tailed Skua *(Stercorarius longicaudus)* and Pomerine Skua (*S. pomarinus*). Only 160 km^2 of Lake Turkana is protected, while Ferguson's Gulf has a large number of water birds but it has no protected area status.

Lake Nakuru is situated in a national park. The lake has large concentrations of the Lesser Flamingo (*Phoenicopterus minor*), the Greater Flamingo (*Phoenicopterus ruber*) and the White Pelican (*Pelecanus onocrotalus*). It is an important wintering and stop-over site for thousands of migratory waterfowl, particularly the Shoveler (*Anas clypeata*). Lake Nakuru, designated as Kenya's first Ramsar site, is typical of other saline Rift Valley lakes which are characterised by low bird species diversity.

Lake Bogoria (42 km^2) is a feeding site for the Lesser Flamingos, mainly from Lake Nakuru and Elmenteita. A game reserve covering an area of 107 km^2 provides protection to the wildfowl in the Lake Bogoria basin.

Lake Naivasha is a freshwater lake with large floating masses of papyrus (*Cyperus papyrus*) and Salvinia (*Salvinia molesta*) (Likens, 1975). The lake water level fluctuates considerably from year to year (Gaudet, 1977), creating temporary mud flats which are extremely important for wading birds. Lake Naivasha has the most diverse wetland avifauna in Kenya with about 400 bird species including 118 water-dependent bird species and 44 water-associated species (Hartley, 1985); it is known for its high density of African Fish Eagles (*Haliaeetus vocifer*) and Red-knobbed Coots (*Fulica cristata*) (Brown and Britton, 1980). The open lake and its muddy and grassy margins support large numbers of wintering ducks, especially between November and February (Meadows, 1984).

The natural water systems outside the Rift Valley are widely scattered and vary considerably in size. The largest wetland outside the Rift Valley is Lake Victoria which has relatively few bird species in the open water. The lake is well stocked with fish and fishing birds, such as gulls and terns, are common on the open water. The Yala Swamp on the northern shores encompasses Lakes Kanyamboli, Namboyo and Sare. This large swamp (160 km^2) is an important ornithological site for Kenya's papyrus endemics such as Papyrus Yellow Warbler (*Chloropeta gracilirostris*), White-winged Warbler (*Bradypterus carpalis*) and the Papyrus Gonolek (*Laniarus mufumbiri*).

The small wetlands outside the Rift Valley, such as Lake Ol Bolossat, Lake Jipe, Tana River Delta lakes, man-made lakes and sewage oxidation ponds, have few resident species of aquatic birds. They are, however, important stop-over wintering sites for migratory ducks; the Garganey (*Anas querquedula*) and the Pintail (*Anas acuta*) tend to inhabit medium-sized wetlands, whilst smaller ducks such as the Hottentot Teal (*Anas hottentota*) and the Shoveller (*Anas clypeata*) inhabit small wetlands including sewage ponds.

Table 4 Important Kenyan wetland habitats for birds

Main habitats category	Examples	Protected area
Indian Ocean littoral		
Mida Creek	Marine National Reserve	
Sabaki Estuary		#
Kilifi Creek		#
Tana River Delta	Proposed National Reserve	
Kiunga Creek	Marine National Reserve	
Dodori Creek	Proposed Marine Reserve	
Rift Valley wetlands		
Permanent lakes		
Lake Turkana	Part National Park	
Lake Baringo	Part National Reserve	
Lake Bogoria	National Reserve	
Lake Kamnarok	National Reserve	
Lake Nakuru	National Park	
Lake Elmenteita	Proposed National Reserve	
Lake Naivasha		#
Lake Magadi		#
Seasonal lakes		
Lake Logipi		#
Lake Alablab		#
Lake Suguta (Maralal)		#
Lake Solai		#
Seasonal swamps		
Ewaso Nyiro (Shombole)		#
Ngong Swamp		#
Musiara Swamp	National Reserve	

Main habitats category	Examples	Protected area
Natural water systems outside the Rift Valley		
Lake Bilisa		#
Lake Jipe	National Park	
Lake Chala		#
Aruba Dam	National Park	
Lake Amboseli	National Park	
Lake Victoria and Yala Swamp		#
Saiwa Swamp	National Park	
Lake Ol Bolossat	Proposed National Reserve	
Moi's Bridge		#
Ahero Rice Scheme		#
Mwea Rice Scheme (Busia)		#
Tana Delta lakes	Proposed National Reserve	
Man-made wetlands		
Hydroelectric dams		
Turkwel River		#
Tana River (Masinga, Kamburu, Gitaru, Kindaruma)		#
Thika River (Samuru, Matuu, Kiyamutwoi)		#
Farm dams		
Sasumua (Aberdares)		#
Nanyuki dams		#
Sewage plants		
Nairobi (Dandora, Eastleigh, Kariobangi)		#
Athi River		#
Thika		#
Machakos		#
Karatina		#
Nakuru		#
Eldoret		#
Kisumu		#
Limuru		#

Relative abundance of waterfowl

A wetland is considered an important waterfowl site if it has a population of more than 20,000 birds (Scott, 1980). This criterion is not necessarily applicable in Kenya. Few sites hold more than 20,000 birds per year; Lake Ol Bolossat in central Kenya had 29,000 palaearctic ducks in 1976 (Cunningham-Van Someren, 1978), but the annual number of palaearctic ducks and other waterfowl remained less than 8,000 birds until 1985. Thus, the number of waterfowl fluctuates considerably from year to year. For the purposes of waterfowl conservation, a population of 10,000 birds is adequate to classify a wetland as being of international importance in Kenya.

The abundance of waterfowl is strongly influenced by local conditions at the census site. Some of the maximum counts of all waterfowl obtained in different types of wetlands in Kenya are shown in Table 5. It is clear that large numbers of waterfowl are not necessarily associated with large wetlands, however, the geographical location of the site and time of year have a strong influence on bird numbers. For instance, Kakuzi Dam in Makuyu (Murang'a District) had 8,000 birds whilst Lake Naivasha had 1,034 birds in 1985. The two wetlands differ remarkably both in size and geographical location: it would appear that it is the location and local food conditions that influenced bird numbers in both wetlands.

Agricultural wetlands are managed by man; the main crops grown are rice, cotton and sugar cane. Rice irrigation schemes are particularly attractive to thousands of waterfowl. Because of temporary fluctuations in food supply for the birds, the planting and harvesting time of crops in agricultural wetlands tends to benefit palaearctic waterfowl which range widely in search of food. The agricultural wetlands around Lake Bogoria and along the Tana and Sabaki River basins are of particular importance to migrating ducks while they are in Kenya.

Conclusion

Birds are an important feature of Kenya's wetlands and about a quarter of the country's avifauna is dependent on wetlands. Thus, wetlands have ample potential for bird conservation. The wetland bird community consists of species which are sensitive to changes in water abundance and chemistry and the structure of aquatic vegetation. For instance, Lesser Flamingos respond to unfavourable food conditions, related to changes in water chemistry, by moving from one saline lake to another in the Rift Valley. Thus, birds can play an important role as biological indicators of environmental change.

The alkaline Rift Valley lakes have high natural productivity and support a large avian biomass. For instance, Lake Nakuru often supports up to one million flamingos, thousands of pelicans and ducks. The lakes have a low avian diversity but are important as feeding grounds for migratory waterfowl. A few resident species, which prefer conditions associated with saline water, reside and breed in the basins of some of these lakes.

Table 5 The relative abundance of waterfowl 1981-1985 (from IWRB, 1985)

Habitat sites	Year	Number of waterfowl
Permanent lakes		
Lake Nakuru	1984	4,030
Lake Naivasha	1985	1,034
Seasonal lakes		
Lake Solai	1984	1,405
Lake Ol Bolossat	1981	1,000
Man-made dams		
Kakuzi Dam	1985	8,000
Kindaruma Dam	1981	35
Aruba Dam	1981	98
Swamps and rice schemes		
Smart's Swamp	1984	150
Ahero Rice Scheme	1983	3,080
Sewage ponds		
Dandora	1985	500
Thika	1985	550

Note: Only the maximum records for one species are shown in each site

Kenya's freshwater wetlands are widely distributed in the country and some, such as Lake Naivasha, Lake Jipe, swamps and marshes, are extremely rich in bird life. Freshwater wetlands provide breeding and feeding areas for a large number of waterbirds. Therefore, wetlands should be given a high conservation and management priority.

Many freshwater wetlands are on privately-owned land in the form of marshes, dams, permanent swamps and fish ponds. For this reason, no single management strategy would be adequate to address the needs for conservation and the landowners. Landowners should be encouraged to utilise wetlands in ways that are compatible with bird conservation. This should be done by providing the necessary incentives to these landowners.

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Wetland fish of Kenya

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Summary

The term 'wetland' groups together a wide range of inland, coastal and marine habitats which share a number of common features. Wetlands constitute unique habitats as they may be subjected to seasonal drying and flooding. They are important as they provide habitats for wildlife and fish; there are at least 48 families of fish living in Kenya's wetlands. Perhaps only a few fish species are strictly wetland inhabitants, the majority of species spend certain parts of the life cycle there and spend most of their adult lives in the pelagic zone. Multiple use of wetlands and their accelerating degradation is recognized.

Introduction

This paper follows the definition of wetlands, as given in the Ramsar Convention, found in the Preface to this volume. The term wetland groups together a wide range of inland, coastal and marine habitats which share a number of common features (Cowardin *et al.*, 1979).

Wetlands are major features of the landscape in many parts of Kenya. They are of great ecological importance as they provide building materials such as mangroves (Dugan, 1990) and papyrus (Lake Basin Development Authority, 1989), water for agriculture and domestic use (Mitsch and Gosselink, 1986; Moris and Thon, 1990) and they are vital for flood control and preserving ground water levels. Wetlands also provide habitats for wildlife (Harper, 1987) and fish (Mavuti, 1989; Okeyo, 1989).

Fish: an historical perspective

Many cultures in Kenya have depended on wetland fish in the past but since the mid-1960s fish numbers have dwindled and some species have disappeared from fishermen's catches (Fryer and Iles, 1972; Achieng, 1987). Before the mid-1960s wetland systems were very stable; riparian vegetation was intact, there was limited industrialization in Kenyan cities and, therefore, low levels of industrial waste. During this time wetland fisheries were usually harvested at subsistence levels using indigenous fishing gear (basket traps, hooks, papyrus seine nets) and there was great species diversity.

In the 1970s and 1980s destabilisation of wetland habitats, related to swift industrial development and population increase, included the clear cutting of riparian vegetation and increased agricultural developments. These activities resulted in increased use of chemicals and associated increased silting which caused the death and suffocation of eggs, and thus reduced recruitment of aquatic organisms. Damming of the Tana and Athi Rivers blocked upstream movement of migratory fish species (Bell-Cross and Minshull, 1988).

Increased exploitation of wetland fish took place when modern fishing gear (nylon line, metal hooks) was introduced (Achieng, 1987). Newly introduced wetland fish species (*Lates niloticus, Oreochromis niloticus, O. leucostictus, Tilapia zillii*) replenished the wetland fisheries but some endemic species disappeared (*O. esculentus* from Lake Victoria, *Labeo victorianus* from the Kuja River) (Fryer and Iles, 1972).

Currently there is hope for the stability of Kenyan wetland ecosystems as some of the fish species which had disappeared are returning.

Wetlands as habitats for fish

There are unique habitats (pans, ponds, dams, reservoirs, lakes, ocean fringes and littorals) for fish in wetlands as distinct from large water bodies and these depend on the status of the watersheds in which they are found. An outline of four families of fish and their relationship to wetlands is given below.

Lungfish

Lungfish (Protopteridae) are found in warm riverine and shallow lacustrine habitats. They are associated with papyrus swamp fringes and water depths of one metre (Greenwood, 1966; Bell-Cross and Minshull, 1988). Lungfish periodically move to the surface to gulp air as they do not remove oxygen from the water like other fish. The substratum is usually muddy and young fish make cavities in the mud where they remain in a quiescent state during the dry season (Greenwood, 1966). The major diet of the lungfish is freshwater snails (Bell-Cross and Minshull, 1988).

Mudfish

Mudfish (Clariidae) are found in rivers with muddy pools. Although preferring quiet stretches of the river (Greenwood, 1966), mudfish will also forage in fast-flowing water and rapids (Bell-Cross and Minshull, 1988). Adult fish are uncommon along the shoreline except at spawning when shoals of gravid females move into flooded areas (Whitehead, 1960; Thisleton, 1965). The mudfish can survive lengthy periods in viscous mud by breathing air. They will colonize newly inundated areas, drainage ditches and perennial pans, where adults are often trapped in isolated pools when the water recedes (Welcomme, 1985). The appearance of these fish in newly-filled pools has given rise to the belief that they can aestivate (Lagler *et al.*, 1977) or remain under the mud surface during the dry season (Greenwood, 1966).

Eels

The eel (Anguillidae) spends much of its time burrowing in mud and crevices, in rivers and lakes, searching for food (Bell-Cross and Minshull, 1988) using its supple body to advantage. Eel populations in freshwater must have an outlet to the sea as spawning takes place in the ocean (Thisleton, 1965). When the female is ready for breeding (sometimes at 20 years of age) she moves downstream to the river mouth where she associates with a male and together they travel across the ocean, perhaps near Malagasy, to breed (Thisleton, 1965; Bell-Cross and Minshull, 1988). The adults die in the breeding ground while the young travel back across the ocean and ascend the rivers to spend their adult life in freshwater. When dams are constructed on rivers, many wetland species, including eels, are trapped behind the dam walls; in Kenya many eels have been thus trapped in the Tana and Athi Rivers. If there was a chance of releasing these eels into the ocean they may spawn (Bell-Cross and Minshull, 1988).

Trout

Trout (Salmonidae) needs clean, fast running, cold waters (Moyle, 1976) and are therefore well suited to Kenya's high wetlands (Government of Kenya (GOK), 1990). The trout can survive in a temperature range of 0°-27°C while the ideal spawning temperature is 12°-26°C. There has been no successful spawning in Kenya's rivers (GOK, 1991a and d) and all rivers are restocked with fingerlings from hatcheries (GOK, 1991a and b). The trout's food consists mainly of macro-invertebrates.

Fish found in wetlands

Some fish species spend all or most of their lives in wetlands. Fishes in the topminnow or livebearer family (Poeciliidae - *Poecillia* spp., *Gambusia* spp.) and some cichlids (Cichlidae - *Haplochromis* spp.) may spend their entire life cycle in wetlands (Greenwood, 1981; Mavuti, 1989). The trouts (Salmonidae), such as rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) may spend their lives in wetland areas or may move to large water bodies (Moyle, 1976; GOK, 1991a). The time spent in a wetland may be determined by size, feeding and spawning requirements. Riverine fishes (Cyprinidae - *Labeo* spp., *Barbus* spp.; Mormyridae - *Mormyrus* spp.; Schilbeidae - *Schilbe* spp.) need wetlands for breeding and feeding; their eggs need running, clear, well-oxygenated water for good recruitment (Moyle, 1976). While juveniles are restricted to wetlands, the adults may develop a pelagic life but return to a wetland at spawning time (Whitehead, 1960).

The families of wetland fish (Table 1) show a great diversity in characteristic, size and habitat preference. For example, members of the Cichlidae may live in fresh, brackish and marine waters (GOK, 1970; Mutagyera, 1978). The majority of riverine fishes (e.g. Protopteridae, Clariidae, Cyprinidae) tend to be widely distributed, are hardy and can tolerate abrupt environmental changes.

Possibilities and practices of swamp fisheries

Swamp fishing is increasing, especially in western and coastal Kenya, yet some species have begun to reappear in fishermen's catches. More fishermen are turning to traditional methods of fishing as the cost of modern tackle increases. Currently there are reasonable prices for fish; in August 1991 Tilapia fillet was fetching 14 KSh/kg at source, therefore many fishermen see this as a reasonable source of income and fishing effort is increased accordingly. At the coast fishermen and women use dugout canoes, small dhows, nets and baskets for collecting fish, molluscs, crustaceans and corals. These products attract good prices, for instance, cocktail prawns were sold at source for 35 KSh/kg in 1989.

Recommendations for conservation of wetland fish

Conservation policy measures require an understanding of scientific aspects of wetlands, balanced with legal, institutional and economic realities, to ensure protection of valuable resources. The following scientific investigations may enable the recommendation of management procedures to the relevant authorities.

1. An inventory of wetlands should be undertaken;
2. taxonomic keys should be designed for wetland flora and fauna;
3. knowledge of socio-economic practices in wetland utilisation should be compared with historical practices;
4. ecological models should be prepared to predict the effects of pollution on wetlands.

Table 1. Fish families reported from wetlands of Kenya

Family	Common names	Author
Anguillidae	eel	Greenwood (1966)
Ariidae*	catfish (sea)	GOK (1991c)
Bagridae	catfish	GOK (1982)
Balistidae*	triggerfish	GOK (1987)
Carangidae*	cavalla jack	GOK (1991c)
Centrarchidae	black bass	Siddiqui (1979)
Centropomidae	nile perch	Trewavas (1983)
Chaetodontidae*	butterfly fish	pers. obs. (1988)
Characiniae (1972)	tigerfish (fresh)	Fryer and Iles (1972)
Cichlidae	tilapia	Greenwood (1980)
Clariidae	mudfish	Mavuti (1989)
Clupeidae	herring (fresh)	Mutagyera (1978)
Cyprinidae (1981)	barbel	Lincer *et al.* (1981)
Cyprinodontidae	guppy	Mutere (1981)
Cynoglossidae (1988)*	tonguefish	Little *et al.* (1988)
Drepanidae*		Little *et al.* (1988)
Hexagrammidae	little mackerel	Mutagyera (1978)
Leiognathidae (1988)*		Little *et al.* (1988)
Lethrinidae (1988)*	scavenger	Little *et al.* (1988)
Lutjanidae*	snapper	GOK (1991c)
Malapteruridae		Mutere (1981)
Mochokidae	catfish	GOK (1991e)
Mormyridae	elephant-snout	GOK (1990)
Mugilidae*	mullet	pers. obs. (1988)
Mullidae*	goatfish	GOK (1987)
Osteoglossidae	arapalma	Mutere (1981)
Platycephalidae (1988)*		Little *et al.* (1988)
Poeciliidae	livebearer	Mavuti (1989)
Pomadasyidae*	grunt	Mutagyera (1978)
Protopteridae	lungfish	pers. obs. (1988)
Salmonidae	trout	GOK (1991a)
Scaridae	parrotfish	pers. obs. (1988)
Schilbeidae	butterfish (fresh)	pers. obs. (1988)
Sciaenidae*	drum	Mutagyera (1978)
Scombridae*	bonito	pers. obs. (1988)
Scorpaenidae*	scorpionfish	pers. obs. (1988)
Serranidae*	rock cod	GOK (1991c)
Siganidae*	rabbitfish	pers. obs. (1988)
Sillaginidae (1988)*		Little *et al.* (1988)
Sphyraenidae*	barracuda	GOK (1987)
Stromateidae*	rock gunnel	NORAD (1984)
Tetraodontidae*	puffer	Mutere (1981)
Theroponidae (1988)		Little *et al.* (1988)

* primarily marine and brackish water fish

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Seasonal wetlands in Nairobi

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Summary

Seasonal wetlands in Nairobi include rock pools, flooded rock slabs, temporary ponds that form in natural or man-made depressions, seasonal springs, seepage areas and flooded grasslands. Each type of seasonal wetland has a characteristic vegetation and a number of rare plants are found only in these habitats. The temporary wetlands provide crucial breeding grounds for amphibians and insects. In addition, fairy shrimp and clam shrimp are found only in temporary pools in Nairobi. The wetlands produce vital food for birds and mammals during breeding and migration seasons; over 225 species of birds have been recorded from one area of temporary wetlands near the Carnivore Restaurant, Nairobi.

Preserving a variety of seasonal wetlands will ensure food supplies for migratory and resident birds, a habitat for rare and endangered plants and aesthetic beauty for the people of Nairobi city.

Introduction

Nairobi may be unique among the world's major cities in not being situated on a large river or the sea. Water, sweet water, is nevertheless the reason for its existence. The springs, streams and swamps of Nairobi guaranteed a supply of fresh water as the railway made its way upcountry. A camp was built, and the city grew.

Today the swamps have long been drained by channelling streams and the planting of eucalyptus trees; drinking water now comes from the slopes of the Nyandarua mountains. A variety of wetlands, however, remains in and near the city. Several streams rise in the Ngong Hills to the south and the ridges to the north, eventually forming the Athi and Nairobi Rivers. Natural springs still feed a number of small swamps in secluded hollows; in places the streams or springs have been dammed, forming ponds. There is even a quaking bog, the Ondiri Swamp, in Kikuyu, not far from the city.

In addition, temporary wetlands are created with the coming of each rainy season. It is these seasonal patches of water that are the subject of this paper. The information is based on field observations made over twenty years.

The site

South of the city centre, between the Uhuru monument on Langata Road, the Langata Barracks, the Carnivore Restaurant, and Nairobi National Park, there is an area of grassland and bush featuring several different and fascinating seasonal wetlands. This is an area of shallow brown soil and rock slabs on a gentle slope. Similar areas of shallow soil and rocky outcrops occur from the Ngong Hills to Thika, separating two major ecological zones - the grasslands that stretch all the way to the slopes of Kilimanjaro and the wooded hills that become the foothills of the Aberdare or Nyandarua Ranges.

Birds recorded on the wetland site are listed in Table 1.

The seasonal wetlands

Rock slabs and rock pools

The rock slabs are formed from tuff (compacted volcanic ash) which is strong, light and somewhat porous; nature's own cinder block and an ideal building stone. In the dry season, the rock slabs look a little like the landscape of the moon - lifeless and grey.

It rains, and the next day the surface of the rocks has changed. Where there was only dry soil and tiny balls of murram, there are now lumps of green jelly. An alga soaks up rainwater and swells, forming sheets of green jelly. The jelly is edible, appearing like manna from heaven.

If the rains continue, the rock pools begin to fill. In the Nairobi area, most rock pools are very shallow - usually only a few centimetres deep and less than one metre across - so they fill quickly, overflow with the next shower and dry out quickly. There is not enough time for most animals to go through their life cycle but, sometimes, the surface of the pools is covered with the grey or purple bodies of springtails (small insects from the order Collembola).

The dry shallow soil on the rock slabs becomes damp and dark. Soon the thin soil is waterlogged. Most plants cannot tolerate these extremes of wet and dry, thus these rock slabs have a characteristic flora. Some plants survive as underground bulbs or tubers, wedged between the rocks. Others shrivel up in the dry season, and turn green with rain almost before your eyes. Still others are annuals whose seeds survive dry periods.

Among the first flowers to bloom on the rock slabs are the lovely lilies *Anthericum gregorianum* and *Eriospermum triphyllum*, which only open in the afternoon, and the rock violets *Craterostigma hirsutum* (Agnew, 1974), as well as *Ilysanthes pusilla* and *Ilysanthes parviflora*. They are followed by grasses, *Eragrostis hispida* on waterlogged soil and *Sporobolus stapfianus* and *Microchloa kunthii* on the shallowest soil, and decorative sedges such as *Kyllinga* and *Mariscus*. At the edges of the rock pools *Murdannia clarkeana* and *Commelina purpurea* start to grow with the rains and towards the end of the rainy season they cover the rocks with blue and orange flowers.

It is here on the rock slabs that the rarest plants on the site occur. *Euphorbia brevitorta* has been collected nowhere else, although there are other sight records. On this site it is restricted to one area of rock slabs, the one nearest the restaurant, where the Nairobi Bypass Road of the Mombasa to Lagos Highway is scheduled to be built.

Other rare plants are the inconspicuous little *Urginea praetoriense*, which in Kenya has only been recorded on rocky outcrops in Nairobi, most of which have become building sites, and the unusual *Brachystelma lineare*, whose flowers smell like cowdung, and which some botanists consider the rarest plant on the site.

Rock pools and rock slabs play a role in slowing down the force of the rain, thus reducing erosion. Some rainwater sinks into the porous rock, reappearing as springs. The pools provide drinking water for birds and other animals during the breeding and migration seasons and a habitat for unusual plants adapted to these extreme conditions. However, they are also prime building sites and are rapidly disappearing from all areas of Nairobi.

Seasonal pools

A number of hollows or depressions occur in this area. Some may be ancient natural pools formed by water flowing over the rocks, others are murram pits dug when the railway line passed nearby many years ago. New pools are also being formed when motorcyclists churn up the ground during motorcrosses or when builders scoop out lorry loads of soil. The hollows are small, ranging from 1-4 m across and a few centimetres to half a metre deep. They fill more slowly than the rock pools because the first few showers sink into the ground. Some of the depressions have a rocky base while others are just low-lying places in the soil.

The plant and animal life of the seasonal pools require alternating wet and dry periods. They would die out if the pools became permanent, just as they would if the pools no longer filled with water. They can, however, stand considerable variation in the amount of wet and dry each season.

In a normal rainy season, the hollows fill with rainwater and come to life. The first rain of the season brings frogs and toads to sing, mate, and lay their strings of eggs where there are no fish to eat them. Their courtship songs fill the night - and even day - with sound. Terrapins appear, perhaps from the National Park, perhaps from the mud.

Insects and other arthropods, such as colourful dragonflies, large diving beetles, fearsome water scorpions, smaller water boatmen and minute midges fly in to lay their eggs in the pools, as do mosquitoes, and frogs and predatory insects arrive to eat them.

Tiny crustaceans, restricted to seasonal pool habitats, hatch from eggs that survive in the dry mud. They include fairy shrimps, clam shrimps, seed shrimps and the tiny copepods. These provide food for the rest of the food chain.

Fairy shrimps look a little like slender prawns, 2-3 cm long and translucent. They swim on their backs, beating their many pairs of flattened legs which also serve as gills. They feed on microscopic organisms and detritus. Fairy shrimps are closely related to brine shrimps, which are used as food for aquariums and in fish and crustacean culture. Unlike brine shrimps, they live in temporary fresh water. Fairy shrimps belong to the order Anostraca, descended from an ancient group of freshwater crustaceans, the Branchiopods ('gill-legs'), which once dominated the waters. Different genera of fairy shrimps are found in pools on rock outcrops in Kajiado, Tsavo, the Serengeti and all over the world. In seasonal pools in the Nairobi-Thika area, fairy shrimps belonging to the genus *Streptocephalus* are found (S. Cooper, pers. comm.). They are whitish, with some iridescent colours, and carry ventral bright pink or red egg sacks. They usually occur in shoals, often associated with tadpoles. Fairy shrimps can be seen in unpolluted seasonal pools a few weeks after the start of the rains and they die after a month or two, even if the pools remain filled with water.

Clam shrimps look like mobile pearls in the water. The little crustaceans, less than one centimetre across, are enclosed between two translucent oval shells. They belong to the order Conchostraca and, like fairy shrimps, they occur in ephemeral pools, where there are no fish to eat them.

Seed shrimps, or Ostracoda, are only one or two milimetres long. They look like glossy rounded seeds and move through the water with astonishing speed. Like the clam shrimps, they are enclosed in glassy shells which may litter the surface like grains of rice, once a pool has dried.

Copepods, barely visible to the unaided eye, are so numerous that sometimes the water appears cloudy with them. They are food for countless insects and crustaceans, which in turn become food for birds, amphibians, reptiles and small mammals. Copepods also live in large bodies of water.

In the rainy season the pools are filled with these delicate little crustaceans but these pools will soon dry out, sometimes remaining dry for a whole year. The crustaceans survive by laying eggs capable of withstanding unusual heat, cold and desiccation. The eggs rest in the dry, dusty bottom of the pool during the dry season and hatch with the next rains. In some cases two kinds of eggs are laid (Findley, 1975); one batch will hatch with the first rains while another will hatch at intervals when the pool has filled. In this way the crustaceans protect themselves against freak storms that fill the pool for only a few days and even drought.

Birds, including storks, ibises, hamerkops, herons, ducks, kingfishers, sandpipers, plovers and painted snipes feed on the tadpoles and invertebrates in the pools. The site sustains more than 218 species of birds (Table 1). The most spectacular bird associated with the temporary pools is the little Yellow-Crowned Bishop (*Euplectes afer*), which nests in the vegetation growing in the pools. Like a giant black and gold bee, the male buzzes around the pool, defending his territory and courting the inconspicuous brown female. After breeding, the bishops leave the drying pools and gather into flocks.

The plants of the seasonal pools in Nairobi are not as spectacular as those of the vernal pools of California, where different kinds of showy flowers form rings around the pools as they dry. The mud at the bottom of the pools may look bare and dry, but as soon as the soil is dampened, water plants begin to grow. *Aponogeton abyssinicus*, with its graceful floating leaves and twin spikes of purple flowers, and a little *Crassula*, with whorled leaves and small pink flowers, soon fill the shallow pools. The orange-flowered *Commelina purpurea* and the blue-flowered *Murdannia clarkeanna*, typical of the rock slabs, may also occur at the rocky or waterlogged edges of the pool.

Several species of sedges grow up through the mud, forming decorative clumps scattered over the pool. *Marsilea*, a floating fern like a four-leaf clover, appears in pools, roadside puddles and drainage ditches, as do *Spirogyra* algae. Each pool on the site seems to have its own personality and its own particular plants. The largest temporary pool is relatively deep, and contains water plants typical of dams and lakes; only one pool is edged with marsh ferns. Different kinds of sedges seem to grow best in different pools. In wet years, some pools become colonized by bulrushes (*Typha*) or the quick-growing shrubs *Sesbania sesban* and *Aeschynomene*.

Natural plant succession can rapidly alter the ecology of the pools. In normal years the pools dry out and so do the sedges. If the rainy season is extended, and the pool does not dry out completely before the next rains, the sedges gradually begin to take over, turning the pool into a marsh. Following the great drought of 1983-84, a rock-lined pool above the survey marker near the army barracks boundary was discovered. For two years it was a beautiful pool, filled with clear water, teeming with tadpoles and invertebrates, and visited by ducks, kingfishers and other waterbirds. The rains were plentiful, the pool did not dry out completely in the dry season and the *Typha* began to grow. First the bulrushes formed an island in the middle, an extremely decorative and excellent shelter for birds. Then they began to spread towards the edges. Now the entire pool is filled with bulrushes, and will remain so until another drought kills them and opens up the pool again.

Typha occurs in several other pools, where reed and pool seem to have struck a balance. Some hollows remain permanently filled with bulrushes; others grow up with each rainy season, then die back with the dry season. Clumps of *Typha* also grow where springs feed a few permanent pools.

Seasonal pools provide crucial breeding sites for insects, crustaceans and amphibians (*Bufo gutterialis, Hyperolius* sp., *Phrynobatrachus* sp.) and thus abundant food for birds and other animals during the breeding and migration season. The pools also check the rush of rainwater and runoff thus reducing erosion.

Table 1 Birds of the Carnivore Restaurant grounds

Hottentot Teal	Painted Snipe
Garganey	Three-banded Plover
Secretary Bird	Blacksmith Plover
Ostrich	Crowned Plover
Pink-backed Pelican	Black-winged Plover
Long-tailed Cormorant	Common Sandpiper
Grey Heron	Wood Sandpiper
Black-headed Heron	Green Shank
Purple Heron	Green Sandpiper
Squacco Heron	Marsh Sandpiper
Cattle Egret	Common Snipe
Great White Egret	Ruff
Yellow-billed Egret	Black-winged Stilt
Hamerkop	Temminck's Courser
Open-billed Stork	Gull-billed Tern
Black Stork	Speckled Pigeon
Saddle-billed Stork	Namaqua Dove
Marabou	Ring-necked Dove
Yellow-billed Stork	Dusky Turtle Dove
Hadada	Red-eyed Dove
Glossy Ibis	Laughing Dove
Sacred Ibis	Green Pigeon
African Spoonbill	Didrick Cuckoo
White-faced Whistling Duck	Klaas' Cuckoo
Egyptian Goose	Great Spotted Cuckoo
Red-billed Teal	Black and White Cuckoo
African White-backed Vulture	Red-chested Cuckoo
Ruppell's Vulture	White-browed Coucal
Egyptian Vulture	Eurasian Nightjar
Lappet-faced Vulture	Montane Nightjar
Eurasian Marsh Harrier	Mottled Swift
Harrier Hawk	Little Swift
Short-toed Snake Eagle	White-rumped Swift
Bateleur	Nyanza Swift
Great Sparrowhawk	Palm Swift
Lesser Spotted Eagle	Speckled Mousebird
Augur Buzzard	Blue-naped Mousebird
Ayre's Hawk Eagle	Pied Kingfisher
Common Buzzard	Malachite Kingfisher
Booted Eagle	Eurasian Bee-eater
Long-crested Eagle	Cinnamon-chested Bee-eater
Gabar Goshawk	Little Bee-eater
Black Kite	Lilac-breasted Roller
Black-shouldered Kite	Eurasian Roller
Lanner Falcon	Rufous-crowned Roller
Lesser Kestrel	Hoopoe
Peregrine Falcon	Grey Hornbill
Kestrel	White-headed Barbet
Red-footed Falcon	Scaly-throated Honeyguide
Harlequin Quail	Eastern Honeybird
Yellow-necked Spurfowl	Nubian Woodpecker
Helmeted Guineafowl	Cardinal Woodpecker
Crowned Crane	Grey Woodpecker
Black Crake	Rufous-naped Lark
Buff-spotted Pygmy Crake	House Martin

Striped Swallow	Tropical Boubou
Red-rumped Swallow	Slate-coloured Boubou
Grey-rumped Swallow	Sulphur-breasted Bush Shrike
African Rock Martin	Brubru
Wire-tailed Swallow	Long-tailed Fiscal
Black Rough-wing	Fiscal
Banded Martin	Red-backed shrike
African Sand Martin	Red-tailed Shrike
Sand Martin	Lesser Grey Shrike
Drongo	Wattled Starling
Black-headed Oriole	Blue-eared Glossy Starling
Pied Crow	Hildebrandt's Starling
White-bellied Tit	Superb Starling
Northern Pied Babbler	Red-billed Oxpecker
Black Cuckoo Shrike	Collared Sunbird
Common Bulbul	Amethyst Sunbird
White-browed Scrub Robin	Malachite Sunbird
Robin Chat	Bronze Sunbird
Rock Thrush	Beautiful Sunbird
Anteater Chat	Golden-winged Sunbird
Isabelline Wheatear	Scarlet-chested Sunbird
Pied Wheatear	Variable Sunbird
Whinchat	Abyssinian White-eye
Northern Olive Thrush	Grosbeak Weaver
Great Reed Warbler	Parasitic Weaver
Lesser Swamp Warbler	Yellow-crowned Bishop
Sedge Warbler	White-winged Widowbird
Yellow-breasted Apalis	Red-naped Widowbird
Little Rush Warbler	Yellow Bishop
Grey-backed Camaroptera	Jackson's Widowbird
Yellow Warbler	Baglafecht Weaver
Singing Cisticola	Spectacled Weaver
Red-faced Cisticola	Chestnut Weaver
Winding Cisticola	Speke's Weaver
Stout Cisticola	Holub's Golden Weaver
Upcher's Warbler	Cardinal Quelea
Olivaceous Warbler	Red-billed Quelea
Brown Parisoma	Grey-headed Sparrow
Buff-bellied Warbler	Rufous Sparrow
Willow Warbler	Red-billed Firefinch Indigobird
Tawny-flanked Prinia	Pin-tailed Whydah
Garden Warbler	Zebra Waxbill
Whitethroat	Waxbill
Red-faced Crombec	Crimson-rumped Waxbill
White-eyed Slaty Flycatcher	Red-billed Firefinch
Spotted Flycatcher	Quailfinch
Chin-spot Batis	Red-cheeked Cordon Bleu
Paradise Flycatcher	Purple Grenadier
Red-throated Pipit	Bronze Mannikin
Richard's Pipit	Cinnamon-breasted Rock Bunting
Tree Pipit	Yellow-rumped Seed-eater
Yellow-throated Pipit	African Citril
African Pied Wagtail	Streaky Seed-eater
Black-backed Puffback	Brimstone Canary

List compiled by Pat Wooton from walks sponsored by the East African Natural History Society. Nomenclature from the East African Natural History Society (1981)

Seasonal springs and seepage areas

As rain falls over the hills of Nairobi, some of the rainwater percolates down through the volcanic tuff. The water emerges as natural springs and seepage areas along the hillsides. Motorists in Nairobi may have noticed that flooded roadways do not always coincide with the lowest point in the road; many roads built in the dry season cut across natural seepage channels and become flooded with every rain.

The springs, like the pools, are temporary, but they usually last well into the dry season. Conditions at the springs are quite different from conditions at the pools; rather than filling quickly, the springs produce a small, but steady, amount of water over most of the year. The spring water trickles down over the rocks, forming clear brooks during the rainy season and for some weeks after the end of the rains. Algae grow in the film of water over the rocks, turning the rock surface black. Velvety clumps of moss and networks of liverworts develop where there is a little soil. *Isoetes*, an unusual primitive plant, occurs in the shallow waterlogged soil near the springs.

Where there are depressions, the spring water forms pools which may be permanent or temporary. Some plants of temporary pools, as well as the tiny *Rotala* and *Ammannia*, are found in shallow water on the edges of semi-permanent pools which shrink and expand with the seasons. Stands of sedges and bulrushes grow on flat ground along the semi-permanent stream beds and pools, creating miniature marshes and swamps. *Habenaria chirensis*, a ground orchid, grows among the grasses in wet ground near the seepage areas and flowers near the end of the rains. *Sesbania sesban*, *Aeschynomene* and *Vernonia* become thickets where the ground remains permanently damp.

The edges of seepage channels, damp for a good part of the year, have their own distinctive flora. *Lobelia anceps*, its flowers like blue faces with white eyes, blooms at the end of the rains. Low-lying plants are the pink *Nesaea*, yellow *Sebaea*, and white *Oldenlandia*. Smaller still is the delicate pink bladderwort, *Utricularia arenaria*. The algae *Nitella* and *Chara*, found in the seepage channels, are rare in the Herbarium collections.

Many animals make use of the wetlands formed by the seasonal springs. Semi-permanent pools and marshes provide important breeding sites for insects and amphibians. Some years ago, the Louisiana Crayfish, introduced in the rivers of the Nairobi area, made their way to the permanent pools. The crayfish, amphibians and water insects in turn provide food for mongooses and other small carnivores.

Small seed-eating birds bath in the pools made by spring water flowing over the rock. Flocks of Zebra Waxbills (*Amandava subflava*), little birds with flaming orange underparts, breed among the reeds of semi-permanent pools. Bulrushes and sedges provide cover for reedbucks and small carnivores and forage for hares, warthogs and reedbucks.

Flooded grasslands

The flat land below the hillside and the adjacent part of Nairobi National Park is an area of black cotton soil. A hardpan layer of clay below the soil prevents rainwater from draining away. Once the soil has absorbed all the water it can hold, the rest remains on the surface, forming flooded grasslands or even pools.

The grasses here are different from those of the shallow, brown soil and deeper, red soil on the hillside. They must survive on clay soil that, although deep, is waterlogged in the rains and dries into cracks during the dry season. *Sporobolus pyramidalis* is the dominant grass, associated with *Bothriochloa insculpta, Eragrostis* and *Setaria*. Whistling thorn trees (*Acacia drepanolobium)* are scattered over the grassland.

Whereas the temporary pools on the hillside fill almost every year, the extent of flooding in black cotton grassland varies widely from year to year. In some years, the grasslands are not flooded at all, while in other years they form shallow lakes for several weeks. Biting blackflies hatch in flooded grassland and can become a nuisance.

The seasonal sheets of water are another important breeding ground for frogs with a short developmental cycle. Flocks of storks, egrets and ibises can be seen feeding on frogs and tadpoles in flooded grassland at the start of the rains. When heavy rains form grassy pools, ducks, lesser moorhens, sandpipers and other waterbirds can be seen. Later, Jackson's Widowbirds (*Euplectes jacksoni*) breed in the tall, thick grass.

Conclusion

Seasonal wetlands are an important part of the ecology of the Nairobi area. Temporary springs provide fresh water for several months. Seasonal pools are the breeding sites of crustaceans, insects and amphibians, vital links in the natural food chain. Rare and beautiful wild flowers occur in the pools and on the associated rock slabs. Some of the plants, frogs and crustaceans are found only in these restricted habitats. In their primary state, the seasonal wetlands sustain their plant and animal life in an ecological equilibrium.

Few seasonal wetlands remain in Nairobi with the rapid growth of the city. Even these are often contaminated and polluted from being used as dumping grounds; deprived of predators, they may become mosquito breeding grounds. Temporary wetlands are usually not taken into consideration by development planners, and roads and buildings constructed on temporary springs later experience many problems.

Areas with rock slabs, rock pools, seasonal pools and seasonal springs have great potential as small parks in which people can walk and relax. The rocky, open conditions offer panoramic views and easy walking. Running brooks and reflecting pools have general aesthetic value, while the great variety of birds and flowers presents a challenge to the naturalist.

The management of these areas for conservation requires protection from littering and destruction by cattle and motorcycles, as well as an understanding of the alternating wet and dry requirements of temporary wetlands to maintain their special nature. The sites look bleak during the dry season and interpretive signs, booklets or guides may be needed for the public to appreciate them at that time.

Preserving a variety of seasonal wetlands in Nairobi would ensure food supplies for migratory and resident birds, a habitat for rare and endangered plants, and aesthetic beauty for the people of the city.

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Mangrove wetlands in Kenya

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Summary

The geographical distribution of mangrove vegetation along the Kenyan coast, in relation to the hydrology, geormophology and hydrography in the semi-arid climate, is reviewed. The zonation patterns of creek mangrove species across the intertidal zone are discussed. The role of mangrove estuaries as nursery grounds is linked to the detritus food chain based on mangrove litter. The leaf material is converted by bacteria, fungi and protozoans and is an important food source for immature stages of many marine animals.

The concentration of juveniles and sub-adults in water around mangroves attracts many carnivorous fish. This implies that the larger the mangrove vegetation cover the greater the ultimate fish concentration in the water around the mangrove forest. The disposal of non-toxic biodegradable organic materials in mangrove forests can be beneficial if they can be converted by the same biological agents that convert mangrove leaf litter.

Introduction

Mangroves are woody trees or shrubs which occur naturally in brackish water or estuarine wetlands in the intertidal zones. They are terrestrial plants which have adapted to life in aquatic habitats that are under the influence of both freshwater and seawater.

Significant adaptations

Mangrove species have evolved morphological and physiological attributes to allow them to occupy soft, muddy, anaerobic environments, to tolerate extreme salinity fluctuations and to use currents for dispersal (Macnae, 1968). However, not all mangroves species show the same morphological or physiological adaptations because they come from different families and genera. In fact their different adaptations allow them to be competitively superior in different niches. The universal requirement for luxuriant growth of all types of mangrove species is a low gradient, marine-brackish water littoral zone with a large tidal range and soil sediments. However, different species show contrasting morphological and physiological adaptations to stresses, especially changes in sediment-size gradient, salinity and wave action. Elaborate rooting systems (depth limits varying between 0.5 m and 2 m) firmly anchor them in the substrate. Some species, such as *Rhizophora mucronata*, have superior stilt rooting systems which provide firm anchorage even where the substrate is almost fluid.

Spongy root structures are a common adaptation. The breathing roots, or pneumatophores, grow above the ground which allows gaseous exchanges in species growing on anaerobic soils. There are various shapes of pneumatophores, such as conical, pencil-like and knee-like found on *Sonneratia alba, Avicennia marina* and *Ceriops tagal* respectively.

Spongy seeds and viviparous propagules can easily be dispersed by currents. Mangrove species such as *Avicennia marina, Lumnitzera racemosa, Xylocarpus granatum, Sonneratia alba* and *Heritiera littoralis* use seed dispersal. *Rhizophora mucronata, Ceriops tagal* and *Bruguiera gymnorhiza* are dispersed as viviparous propagules.

All mangrove species are, to different degrees, salt excluders. *Avicennia marina* can also secrete salt through its leaves. Salt tolerance increases with age; seedlings develop only under brackish water conditions but the various species of adult mangroves can survive in salinities ranging from almost freshwater to seawater.

However, mangroves have maintained most of their terrestrial characteristics, a fact that has been exploited to grow them artificially on wetlands or irrigation systems away from the sea (even in backyards of homes) after establishing the seeds or propagules in nurseries and then transplanting the young plants (B. Clough, pers. comm. 1990). Nevertheless, successful flowering, fruiting and production of viable seedlings from mangroves grown in artificial habitats away from the sea are yet to be reported.

The pollination of mangrove trees still depends on insect activity and they have therefore maintained sweet-smelling, colourful flowers to attract insects to pollinate them. There is also the possibility of pollination by wind and bats.

Mangroves carry out photosynthesis through their green leaves; their canopy is therefore positioned predominantly above the high water mark. Like some terrestrial plants, mangroves also have the ability to grow on hard substrates with only superficial soil or sediments e.g. coral rocks or reefs. Their firm rooting systems in the crevices of coral rocks support them against heavy wave action.

Distribution of mangroves in Kenya

The Kenya coastline (Figure 1) has about 53,000 ha of mangroves (Doute *et al.*, 1981) occurring mostly in creeks, bays and estuaries (Table 1). However, the bulk of the mangrove cover occurs in areas far away from the estuaries of the only two permanent rivers, the Tana and Sabaki Rivers. The geographical distribution of the mangroves is related to the shoreline configuration, geomorphology and hydrology, especially the submarine ground water discharges (SGD) which create the brackish water conditions required for successful development of the propagules and seeds upon settlement.

The following are the descriptions of the climatological, geomorphological and hydrological features which profoundly influence the patterns of distributions of mangrove cover along the Kenyan coast.

Climate

The climate along the Kenyan coast is under the influence of two distinct monsoon wind patterns (Isaac and Isaac, 1968). The major monsoon wind pattern, the South East Monsoon (SEM), is present from April to October and is characterised by winds which generally blow towards the mainland from a southeasterly direction. The second monsoon season, the North East Monsoon (NEM), blows from November to March with winds from the northeast. The winds are stronger and more moist during SEM than in NEM. During SEM the rainfall ranges from 55-272 mm/month and temperature from 20°-31°C whereas in the NEM the rainfall and temperature ranges are 8-84 mm/month and 23°C and 32°C respectively.

While the SEM usually begins in April, most of the rainfall occurs in the month of May (240 mm). Rain peaks in the NEM occur in either November or December.

Geomorphology

The indented parts of the coastline are found north of Mida Creek and south of Gazi Bay (Figure 1). There are several sheltered waterways sandwiched between islands in Lamu and Kwale Districts. Parts of the coastline are bordered by limestone cliffs which are predominantly composed of Pleistocene coral (Crame, 1980 and 1981).

The Kenya coastline is inclined in a southwest to northeast direction, between longitudes 39°12'E and 41°35'E and latitudes 10°37'S and 1°30'S, which generally reduces the wind impact on shorelines during the NEM. Most of the creeks are inclined northwest to the coast, thus the East African coastal current has a significant influence in geological and physical processes of the creeks.

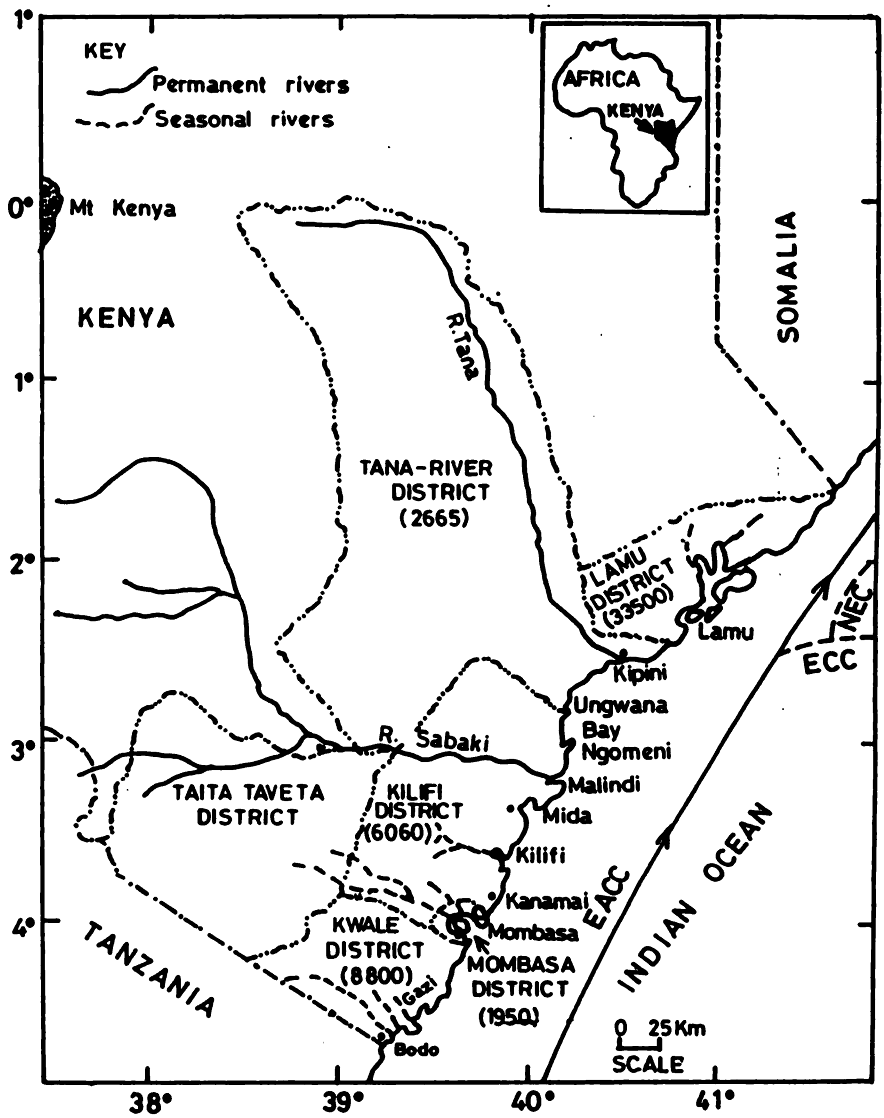

Figure 1 Map of Kenyan coast showing drainage, circulation pattern and mangrove area (ha) by district. See text for names of ocean currents

Considerable erosion and deposition of sediments occurs along the Kenya coastline. Such sediments are a product of deposition of both marine and continental sediments from the Permo-Triassic period to the present day. The areas around Ungwana and Malindi Bays are principally depositional, shallow water environments which receive most of their sediments from the hinterland *via* the Sabaki and Tana Rivers (Dubois *et al.*, 1985).

The Kenyan coast has a narrow continental shelf. South of Malindi the shelf is about 5 km offshore but north of Malindi, in the North Kenya Banks, it is about 59 km offshore. The coastline has a protective fringing reef which lies 0.5-2.0 km offshore.

Hydrology

Besides the surface flowing rivers, considerable SGD flows into the sea along the entire shoreline (Ituli, 1984). The Tana and Sabaki Rivers discharge freshwater all year, especially during the SEM. The seasonal rivers may dry up during the NEM and during this season, SGD is the most significant source of freshwater contributing to brackish water conditions.

The salinity of the coastal waters at the living coral reef and in the open sea usually ranges from 35-36 ppm (Kazungu *et al.*, in press). However in estuaries, the salinities are lower, especially during rainy seasons, and may range from 2 ppm, in areas with river inflows, to 36 ppm near the open sea (Kazungu *et al.*, in press). In the backreef, where SGD occurs, pools of lower salinities (24-30 ppm) are frequently encountered during low tide in the lower eulittoral zone (Ruwa and Polk, 1986). Measurements taken directly at the discharge points may be as low as 6 ppm.

Hydrography

The hydrography of the Kenyan coastal waters is determined by the major circulation patterns in the Western Indian Ocean region (Newell, 1957). The entire Kenyan coastal waters are under the influence of the northward flowing East African coastal current (EACC) throughout the SEM. EACC is the northward deflection of the eastward flowing South Equatorial Current (SEC), caused when the latter meets the African continent landmass. During the NEM, the north of Ungwana Bay is under the influence of the southward flowing North Equatorial Current (NEC), with watermass from the Arabian Sea. Where the NEC and EACC converge they form the eastward flowing Equatorial Counter Current (ECC), which exists only during NEM.

Other major hydrographic patterns are tides and wave action. The tidal range is from 4 m, during some spring tides, to 1.4 m, during some neap tides (Brakel, 1982). The intensity of wave action varies greatly along the Kenyan coastline. Sheltered shores, in creeks and bays, experience less wave action than exposed shores which directly face the windward side of the open sea. During the SEM, winds are stronger and wave higher than in the calmer conditions of the NEM.

Mangrove cover

Following the terminology of Macnae (1968), there are two types of mangrove formations along the Kenyan coast. Creek mangroves are found in low gradient shores, in creeks and bays, and cover extensive areas. Fringe mangroves are solitary or are in clusters of a few trees; they are found in high energy shores, in front of rocks or cliffs.

The most common mangrove formations occurring along the Kenyan coastline are the creek mangroves. The largest mangrove cover, of 30,475 ha, is found in the Lamu complex area (see Table 1). It is notable that the existence of a mangrove forest, covering 1,600 ha, at Mida Creek, is due to brackish water conditions caused entirely by SGD.

Mangrove species composition

The are eight species of mangrove trees and shrubs found along the Kenyan coastline (*Rhizophora mucronata*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Sonneratia alba*, *Avicennia marina*, *Lumnitzera racemosa*, *Xylocarpus granatum* and *Heritiera littoralis* (Isaac and Isaac, 1968; Kokwaro, 1985). Except for *Heritiera littoralis*, all the species are commonly encountered along the River Tana estuary and in areas around Lamu. The geographical distribution along the Kenyan coastline is summarized in Table 2. Vegetation surveys have been confined to easily accessible shores and there is a need for a more thorough search to determine the distribution of mangrove species along the coastline.

Zonation of mangroves

Different mangrove species are found at different shore levels but with some overlap. In macro-tidal shores, with vast low-gradient shore profiles, mangrove zonation may be conspicuously seen. Mangroves are true inter-tidal plants which naturally grow between mean low water neap (MLWN) and extreme high water spring (EHWS).

Studies in Kenya have established that mangrove species may be zoned in creek mangrove formations (Ruwa, in press a and b). Transect studies at Gazi and Ngomeni show zonation in abundance of the major species. Moving from extreme low water spring (ELWS), either *Rhizophora mucronata* or *Sonneratia alba* was the outermost species, followed by *Ceriops tagal* in the intermediate shore levels. *Avicennia marina* was found at the highest shore level. There is some overlap of zones, which may be considered to be ecological noise. For example, *A. marina* was found at its lower levels in the major zones of *S. alba* and *R. mucronata* but formed almost pure stands at the highest shore levels (see Table 3). *B. gymnorhiza* trees were found among the major zones of *R. mucronata* and *C. tagal*. *Xylocarpus granatum* trees were scattered and frequently occurred among *C. tagal*. Trees of *L. racemosa* predominted among the *A. marina* but could extend landward to form a fringe at the upper limits of this zone.

Where there are environmental gradients and the organisms show different tolerance levels, zonation will occur. Biotic factor gradients (predator pressures or superior growth patterns) may cause dominance in competition for resources which leads to zonation. Abiotic factors in the marine littoral zones can be used to determine zonation across shores with regular, large tides in non-cyclone zone areas. Most abiotic factors in the littoral zone are profoundly influenced by tides and shore gradients. Mangroves have been shown to exhibit zonation where environmental gradients across the littoral zone occur (Macnae, 1968; Snedaker, 1982) but proof of zonation due to biotic factor gradients is yet to be established.

The prominent mangrove species in the Western Indian Ocean are *R. mucronata*, *C. tagal* and *A. marina*. In all the coasts of this region they occur in this sequence in an upward-shore direction where environmental gradients exist (Macnae and Kalk, 1962; Macnae, 1971; Hartnoll, 1975). With minor exceptions the mangrove species in Kenya follow the same pattern; except when *S. alba* occurs as the major lowermost species.

Associated flora and fauna

The mangrove forests support both terrestrial and aquatic flora and fauna.

Terrestrial component

The terrestrial fauna includes birds, reptiles, mammals (pigs, monkeys) and insects (wasps, mosquitoes, ants, etc.). The terrestrial flora is less diverse, being mostly fungi, lichens and mistletoes. The arboreal macrofauna of the Kenya coast was reviewed by Ruwa (1990).

Aquatic component

The aquatic component consists of many species of flora and fauna (see Ruwa, 1984 and 1990). The organisms may be found attached to the trees, in the soil and in the water medium around the mangrove trees. A review of mangrove macroalgae is found in Coppejans and Gallin (1989). Penaeid prawns and various families of fish (Clupeidae, Carangidae, Cynoglossidae, Drepanidae, Leiognathidae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Pomacentridae, Pomadasyidae, Platycephalidae, Serranidae, Siganidae, Sillaginidae, Sphyraenidae, Theraponidae) are associated with mangroves (Brusher, 1974; Wakwabi, 1988; Little et al., 1988a).

There have been various questions asked about the various biota found in mangrove biotopes. Are those species that require hard substrates found on mangroves because they offer hard substrate? Are the organisms there because of the estuarine or brackish water conditions on which the mangrove also depends?

Table 1 Areas of mangroves on the Kenyan coast (Doute *et al.*, 1981)

Locality	District	Area (ha)
Kiunga	Lamu	3,025
Lamu	Lamu	30,475
Kipini (Witu)	Tana River	1,595
Mto Tana (Witu)	Tana River	250
Mto Kilifi (Witu)	Kilifi and Tana River	2,335
Mto Fundisha (Formosa Bay)	Kilifi	330
Ngomeni	Kilifi	1,815
Mida Creek	Kilifi	1,600
Takaunga	Kilifi	30
Kilifi Creek	Kilifi	360
Mtwapa Creek	Kilifi and Mombasa	525
Tudor Creek	Mombasa	1,465
Port Reitz	Mombasa and Kwale	1,575
Maftaha Bay (Gazi)	Kwale	615
Ras Mwachema	Kwale	5
Funzi Bay	Kwale	2,715
Vangu	Kwale	4,265
Total		52,980

Table 2 **Geographical occurrence of some mangrove species found along the Kenyan coast**
P = species present

Species	Gazi	Kibarani	Tsunza	Bamburi	Mida	Sabaki	Ngomeni	Bodo	Mkomani	Kwa Jomvu
Avicennia marina	P	P	P	P	P	P	P	P	P	P
Bruguiera gymnorhiza	P	P	P	P	P	P	P	P	P	P
Ceriops tagal	P	-	P	P	P	-	P	P	-	P
Lumnitzera racemosa	P	-	-	-	-	-	-	P	-	-
Rhizophora mucronota	P	P	P	P	P	P	P	P	P	P
Sonneratia alba	P	P	P	P	P	P	P	P	P	P
Xylocarpus granatum	P	-	-	-	P	-	-	P	-	-

Table 3 **Summary of the distribution of various species of mangroves across creek forests based on transect studies at Gazi and Ngomeni**
MLWN = mean low water neap; MTL = mean tide level;
MHWN = mean high water neap; EHWS = extreme high water spring

Species found between	MLWN and MTL	MHWN and MTL	MHWN and EHWS
Avicennia marina	Rare	Common	Very common
Bruguiera gymnorhiza	Common	Common	Common
Ceriops tagal	Common	Common	Rare
Lumnitzera racemosa	-	Common	Very common
Rhizophora mucronata	Very common	Common	-
Sonneratia alba	Common	Common	-
Xylocarpus granatum	Rare	Common	Rare

Similarly it can be argued whether a typical mangrove ichthyofauna can be distinguished if those fish are found in the mangrove biotopes because of the estuarine conditions rather than the presence of mangroves. The closeness with other biotopes, like living coral beds and seagrass beds in lagoons, permits easy access among these biotopes and therefore makes it difficult to distinguish the particular biotopes of residence. A fish species may occur in the mangrove biotope for only part of its life cycle. These fish come specifically for spawning or feeding. The role of estuaries as nursery areas in both the non-mangrove temperate and mangrove tropical zones has been described (Little *et al.*, 1988a and b). The latter reflects the importance of the universal brackish water conditions in the development of young stages of fish and other fishery organisms. Temperate estuaries characteristically have salt marsh vegetation whereas tropical estuaries often have mangrove vegetation. But whereas the brackish water condition is a significant requirement for the presence and development of the organisms, the major significant role of mangroves in improving the nursery conditions of estuaries in the tropics is based on its high primary productivity and leaf litter fall which is unparalleled by any other estuarine flora (Table 4).

Leaf litter from mangroves contributes significant energy through the detritus-based food chain, hence improving fish yields (Heald and Odum, 1970). The link between fish and mangrove litter explains the positive role of mangroves in enhancing fish yields and eliminates the idea that the fish may be there only because of the estuarine conditions, on which the mangroves also depend. Whereas larval and juvenile fish, prawns and other invertebrates ingest detritus, previously converted by bacteria, fungi and protozoans, the juvenile fish attract larger predators which feed on them. Thus the mangrove biotope acts both as a nursery ground for the young and a feeding ground for adult or sub-adult fish (Brusher, 1974; Little *et al.*,1988a and b; Wakwabi, 1988).

Table 4 Primary productivity in various tropical biotopes

Biotopes	Productivity g C/m^2/year	Source
Mangrove forest	5,112	Lugo and Snedaker, 1975
Mangrove leaf litter	366-1,464	Snedaker and Brown, 1982
Phytoplankton		
Open sea	50	Ryther, 1969
Continental shelf	100-150	Ryther, 1969
Upwelling areas	300-500	Ryther, 1969
Seagrass	8	Thorhaug, 1981
Sand beach	5	Steele and Baird, 1968

Prawns arrive in the creeks as larvae and survive on detritus in the mud. As sub-adults they migrate back to the sea (Brusher 1974). Significant, positive correlations between mangrove forest and fish and prawn landings have been demonstrated (Brakel, 1982), which suggests that fishery landings could drop if mangroves are overexploited.

Mangroves act as nutrient traps and therefore reduce nutrient loads into the sea from submarine ground water discharges (SDG) and rivers thus encouraging luxuriant growth of seagrasses (UNESCO, 1987). In areas where nutrient levels are high, the seagrasses carry considerable loads of epiphytic algae. The epiphytes compete with seagrasses for light and, in extreme cases, fleshy algae may dominate the seagrasses.

All the macroflora seen in Kenyan mangrove biotopes (Coppejans and Gallin, 1989) can be encountered in other brackish water areas where suitable hard substrate for attachment exists (Oyieke and Ruwa, 1987). Animal species confined to creek mangroves include *Uca gaimardi*, *Sesarma meinerti*, *S. ortmanni*, *S. eulimene*, *Sarmatium crassum*, *Cardisoma carnifex*, *Cassidula labrella* and *Cerithedia dectolata*. Thus there is growing evidence that a distinct and characteristic macrofauna exists in mangrove biotopes (Warner, 1969; Frith *et al.*, 1979).

A less significant but equally important component of the plant life found in the exposed salt marshes, in bare high-shore areas of the mangrove forest, are *Salicornia* spp., *Sesuvium portulacastrum*, *Ipomoea pes-caprae*, *Vigna marina*, *Juncus* spp. and *Athrocnemum* spp. These are considered to be maritime halophytes of the mangroves.

Conclusion and recommendations

The Kenyan coast is not particularly endowed with extensive mangrove forests and the present forests need to be carefully managed for sustainable use. Only scanty information on mangrove biotopes in Kenya is available for planned management strategies. Although the world literature on mangroves is overwhelming, and has provided guidelines on management strategies, it cannot be applied without understanding Kenya's mangrove ecosystems. Noting that the Kenyan coastline is semi-arid, and the major mangrove forest cover depends on SGD, mangrove management must be sensitive to management of ground water aquifers. Species of mangroves, like *Heritiera littoralis*, which require very low salinities, will be adversely affected by activities that reduce the supply of fresh water. *H. littoralis* shows very localized distribution patterns and needs more attention than the other species. There should be attempts to increase the mangrove distribution and cover by introducing mangroves in brackish water beaches that have not yet been naturally colonized and to reintroduce them where they have been destroyed. Mangrove cutting should go hand-in-hand with replanting. Creation of mangrove nurseries is now a necessity.

As well as the need for more research, there is also an immediate need to initiate public awareness education programs on mangroves. Unlike terrestrial wildlife reserves, mangroves forests have yet to be popular tourists areas in East Africa. But there is potential for mangrove parks need to be created: walking platforms could be constructed across the forests to allow people to avoid the mud and acquire first-hand information on mangrove life. Not many people have seen seeds of plants which begin growing when they are still attached to the parent plant. Guided education walks would increase interest in mangroves and facilitate attempts to protect them.

The role of estuarine areas as nursery grounds for various fishery organisms is well known and selective fishing methods are often used to avoid juveniles. However, there is a need to undertake leaf decay studies of various brackish water plants to understand the superior qualities of mangrove leaves in the detritus food chain. There is also a need to research the metabolism of non-toxic, biodegradable solid wastes by mangrove organisms to establish how successfully they are converted and their role in the detritus-based food chain. This information may assist in the problem of solid waste disposal in mangrove ecosystems, which is common in all urban areas along the Kenya coast.

Regular ecological monitoring studies on mangroves are required; for these to be successful, support from environmental groups, the Government, institutions and non-governmental organizations is necessary.

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Classification and vegetation of freshwater wetlands

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Introduction

The term 'wetlands' covers a wide range of habitats which share common characteristics. It is relatively difficult to find a single, correct, indisputable, ecologically sound definition for a wetland. This is primarily due to the diversity of wetland ecosystems and the fact that demarcation between dry and wet environments lies along a transition.

The Ramsar Convention definition of wetlands can be found in the Preface of this document. The International Biological Programme (IBP) regarded wetlands as areas distinct from open water and for inclusion in wetlands, water is usually characterised by having emergent vegetation (Worthington, 1976). In this discussion wetlands will be regarded as areas transitional between terrestrial and aquatic systems where vegetation is flooded, either permanently or seasonally.

Classification of wetlands

Freshwater wetlands in Africa may be conveniently divided into six major categories: swamps, marshes, floodplains, bogs, agricultural and artificial wetlands.

Swamps

Swamps are aquatic systems although some interaction with the surrounding terrestrial areas may occur. Swamps are characterised by the presence of emergent macrophytes which are flooded to a shallow depth either permanently or for most of the year. This is a prominent wetland type in many parts of Africa; the Sudd in Sudan covers 150,000 km^2 in the upper Nile (Etherington, 1983).

In tropical Africa two major types of swamps have been recognized (Symoens *et al.*, 1981); those in which the dominant plants are rooted in the sediments and those in which the dominant plants are rooted in a floating mat. The former swamps are dominated mainly by cattails (*Typha*) and reeds (*Phragmites*) while the latter are dominated by *Vossia cuspidata* (water grass) and *Cyperus papyrus* (papyrus). The floating papyrus swamps are the most prominent and the best known swamps.

Marshes

This type of wetland could best be differentiated from swamps in terms of water retention time and species composition. The vegetation of marshes is generally shorter than that of swamps. Marsh vegetation is also more open thus allowing greater light penetration to the marsh water. Typical marsh communities include those dominated by sedges such as *Cyperus articulatus* and hygrophilous grasses such as *Echinochloa* spp.

Floodplains

Floodplains are areas along the course of rivers where large seasonal variations in rainfall result in flooding and the overspill from the main channel flows into the surrounding plains. Extensive floodplains occur along the Nile in Egypt and Sudan, the Pongolo plains in Natal and the Rufiji plains in Tanzania. Floodplains may also occur in areas surrounding lakes, as around Lake Bangweulu in Zambia and Lake Chilwa in Malawi, which may be dry for most of the year but flood for a short period after the rainy season. Floodplain flora is made up of mostly hygrophilous grasses such as species of *Echinochloa, Oryza, Cynodon, Pennisetum* and *Sporobolus*.

Bogs

Montane or alpine zone wetlands are referred to as bogs (Thompson and Hamilton, 1983). Bogs in Africa are generally located in high cool areas and are found in Lesotho and East African mountain areas. The bog ecosystem is characterised by a dominant vegetation of *Sphagnum* moss, has low rates of decomposition and hence high peat accumulation.

Agricultural wetlands

Agricultural wetlands include irrigated lands, irrigation canals and ditches. These wetlands have played an important part in civilization; today, agricultural wetlands colonized by the domesticated reed swamp grass, rice (*Oryza sativa*), feed more than half of the world's population.

Artificial wetlands

Man's need for irrigation water and hydroelectricity has created new wetland areas; water storage areas or reservoirs which range in size from small village ponds to huge man-made lakes such as Lake Kariba. These wetlands attract a wide assemblage of flora including the aquatic weeds *Salvinia molesta, Eichhornia crassipes* and *Pistia stratiotes*.

Wetland vegetation

The vegetation of African wetlands has recently been reviewed by Symoens *et al.* (1981) and Denny (1985). Wetland vegetation includes plants which grow in water or are found predominantly in wet places such as swamps and marshes. These plants are divided into two broad categories; aquatic microphytes and aquatic macrophytes.

Aquatic microphytes

The aquatic microphytes consist of an array of small plants, or algae, which contain chlorophyll and hence are able to produce organic matter through photosynthesis. Most of the microphytes fall under the category of phytoplankton, which in general are the major primary producers in aquatic ecosystems. One of the most important groups is Chlorophyta - green algae. This is an extremely large and morphologically diverse group and includes algal organisms such as *Volvox*, *Scenedesmus* and *Pediastrum*.

The diatoms (Bacillariophyta) are perhaps the most important members of the freshwater phytoplankton. In many lakes they are present in significant numbers and dominate. The group is commonly divided into centric diatoms (*Cyclotella*, *Stephanodiscus* and *Melosira*), exhibiting radial symmetry, and pennate diatoms which are bilateral. The pennate diatoms include species of *Asterionella*, *Synedra*, *Navicula* and *Nitzschia*.

The Pyrrophyta (dinoflagellates) are unicellular flagellated algae, such as *Ceratium*, many of which are motile.

Cyanophyta (blue-green algae) is a relatively primitive group of algae. Like bacteria, the blue-green algae are prokaryotic; the cells are undifferentiated and lack membrane-bound nuclei, mitochondria, plastids and internal membranes. Examples of blue-green algae include *Microcystis*, *Oscillatoria*, *Lyngbya* and *Anabaena*.

Almost all the euglenoids (Euglenophyta) are unicellular; they lack a distinct cell wall and possess one , two or three flagella. When conditions are favourable, euglenoids can proliferate to form algal blooms. Examples of euglenoids are *Euglena* and *Phacus*.

Aquatic macrophytes

The aquatic macrophytes include the charophytes (stoneworts), bryophytes (mosses and liverworts), pteridophytes (ferns) and spermatophytes (seed-bearing plants). Aquatic macrophytes can be divided into four major groups on the basis of their life form: emergent, submerged, floating-leaved and free-floating.

Emergent macrophytes

Emergent macrophytes are rooted in the substrate and produce emergent (above water surface) vegetative shoots. These plants dominate in many swamps and marshes and often form fringing vegetation around lake shores. Typical emergent macrophytes include papyrus (*C. papyrus*), reeds (*Phragmites*) and cattails (*Typha*).

Free-floating macrophytes

These macrophytes normally float on the water surface and their distribution is largely dependent upon wind and water movements. This group of aquatic macrophytes include members of Lemnaceae (duckweeds) such as *Lemna, Spirodela* and *Wolffia* as well as the aquatic weeds *E. crassipes, S. molesta* and *P. stratiotes*.

Floating-leaved macrophytes

Floating-leaved macrophytes are rooted in the substrate and produce leaves which float on the surface of water. They include members of Nymphaceae (water lilies), such as *Nymphaea lotus* and *N. nouchali caerulea*, and also *Potamogeton* spp.

Submerged macrophytes

Plants which are rooted in the substrate and have all their vegetative parts below the surface of water at all times are submerged macrophytes. They include plants like *Hydrilla, Ceratophyllum, Vallisneria* and *Najas*.

Vegetation zonation

Where wetlands border lakes and rivers, the vegetation shows a succession of zones between the shore and the open water; each zone with its own unique plant community. Zonation in African wetlands has been described by several authors including Beadle (1932), Eggeling (1935), Lind and Visser (1962) and more recently by Gaudet (1977).

Passing from the dryland to open water, three broad zones of vegetation are recognized. Bordering the dryland is a grass/sedge zone dominated by hygrophilous grasses, such as *Miscanthidium, Loudetia, Pennisetum, Echinochloa* and *Cynodon*, associated with members of Cyperaceae.

This landward zone gradually gives way to a zone of littoral macrophytes usually dominated by a monoculture of emergent plants such as *Typha, Phragmites* or sedges such as *Cyperus papyrus*. This is the most extensive zone which merges into the open lake through an intermediate zone of both floating and submerged macrophytes.

At the swamp/water interface are thick beds of submerged and floating plant communities. The submerged macrophytes are dominated by *Ceratophyllum demersum* which is interspersed with species of *Najas, Utricularia, Potamogeton, Nitella* and *Chara*. The floating macrophyte community may be dominated by *S. molesta*, *P. stratiotes* or colonies of *Lemna* and *Wolffiopsis*. The above description occurs only where the swamp merges into the open water body. The situation, however, may change during periods of low water.

Drawdown flora

Many tropical lakes experience a cycle of flooding and subsequent receding water level from the lake edge. This phenomenon is referred to as drawdown, a term used in describing a drop in water level in man-made lakes when water is drawn off for man's use.

During drawdown the fringing swamp is stranded as the water level falls and a considerable expanse of mud is exposed between the swamp and the retreating water. Seeds in the exposed mud germinate and a large community of drawdown flora is established.

The plant community in the drawdown area has been described by Gaudet (1977) in Lake Naivasha. It is composed of seedlings and young plants of several species including sedges (including *C. papyrus* and *C. immensus*) and large populations of composites (such as *Conyza, Gnaphalium* and *Sphaeranthus*). The majority of the drawdown flora is not strictly aquatic and may better be described as hygrophilous ephemerals.

During the high water season most of the drawdown flora is covered with water and eventually dies. The decomposing plants release large quantities of nutrients into the lake.

Recommendations

Generally, wetland communities in Kenya have been considered by policy makers and the public to be of little use. Thus until recently their disappearance has caused little alarm, except to some members of the scientific community and conservationists. This lack of concern for wetlands is partly attributed to the paucity of scientific information on their structure, composition and function. The wetland vegetation is an integral and essential part of the complex aquatic system.

There is a need to fund research projects in wetlands so that the scientific information generated can be used in the formulation of sound policies for wetland management and conservation. Data from research will also be used in the preparation of wetland manuals and other publications, which will increase the understanding of wetlands systems and raise awareness of the problems affecting these vital systems.

Vegetation surveys of all wetlands in Kenya should be carried out and an up-to-date inventory compiled.

There is a need to formulate a wetlands policy which will give adequate protection to the existing wetlands and halt the current trend of reclamation.

There should be thorough environmental impact assessments on projects that interfere with the structure and function of wetlands. In such circumstances, scientists with local knowledge should participate in the environmental impact assessment processes.

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Floating aquatic weeds in Kenya

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Summary

Three species of plants, salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes)* and water lettuce *(Pistia stratiotes),* are responsible for most of the floating aquatic weed problems in Kenya and throughout the tropical world. These three floating aquatic weeds have infested the wetlands of Kenya at different times and with varying degrees of spatial extent; all three of them have infested Lake Naivasha.

The weeds are native to the Amazon basin. Outside their natural habitats they are freed from the controlling influence of their natural enemies and their unchecked growth results in thick mats of vegetation. This has a deleterious effect on water quality, fish populations, underwater macrophytes, irrigation schemes, hydroelectric power generation and navigation as well as causing the loss of biological diversity in the infested aquatic ecosystems.

Salvinia is the most problematic weed in Kenya covering up to 25% of the water surface of Lake Naivasha. Water hyacinth has only recently been observed in natural water bodies. Water lettuce is found in most of the freshwater wetlands of Kenya and is a problem in the coastal region.

Mechanical, chemical and biological methods of controlling salvinia have been tried in Lake Naivasha without success. Host-specific natural enemies are now available to control the three floating aquatic weeds. What is required is the training of local scientists and the importation of starter colonies of these biological control agents. This relatively inexpensive programme will reduce existing infestations and possibly prevent the spread of these weeds to other wetlands in Kenya.

Introduction

The aesthetically pleasing appearance and unique growth form of floating aquatic weeds have been responsible for their being spread to various tropical and subtropical countries by man during the 1800s and early 1900s. They were used to grace aquaria and ornamental ponds whence they escaped into natural or artificial water bodies and became serious aquatic weeds.

Whereas indigenous plants are in equilibrium with their parasites and predators, these alien macrophytes proliferate in new nutrient-rich habitats due to the absence of their natural enemies. The excessive growth forms dense mats on the water surface causing adverse ecological effects on natural and man-made aquatic ecosystems. These effects include interference with navigation, fishing activity, domestic water supply, irrigation, recreation and disease control. Dissolved oxygen is depleted and underwater biota are shaded out; competition with indigenous plants for available nutrients occurs and leads to a loss of aquatic biodiversity. All these problems lead to reduced productivity and general degradation of the infested wetlands.

In Kenya, the floating aquatic weeds are salvinia (*Salvinia molesta)*, water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). In some wetlands, as in Lake Naivasha, all three weeds are found.

Occurrence and characteristics of the floating aquatic weeds

Salvinia

Salvinia molesta Mitchell (previously identified as *Salvinia auriculata*) is commonly known as salvinia, Kariba weed or water fern and is a free-floating aquatic fern of the plant family Salviniaceae. It originates from south-eastern Brazil (Forno and Harley, 1979) from where it has spread to most tropical and subtropical regions of the world.

Unlike other aquatic ferns and most of the other vascular plants, salvinia is a sterile pentaloid, the entire species apparently being one clone whose population dynamics depend entirely on branching growth and fragmentation. Salvinia has no true roots but sends out a very dissected, hairy, submerged leaf which absorbs nutrients and acts as a stabilizer (Gaudet, 1976). Under optimum conditions, a salvinia plant will double its size in 2.2 days (Harley and Mitchell, 1981).

The introduction of salvinia to Kenyan wetlands occurred in the early part of this century. It was cultivated in ornamental pools and aquaria in Nairobi by 1936 (Gaudet, 1976), then escaped into the Nairobi-Athi River and subsequently spread to other wetlands. Salvinia was confirmed in Lake Naivasha in 1962 (Hiscock, 1970) and by 1980 it had formed a thick mat in the littoral areas and had even invaded the more saline Lake Oloidien to the southwest of the Naivasha Basin (Njuguna, 1982). In 1988, salvinia covered up to 25% of Lake Naivasha's water surface. The weed is particularly troublesome during periods of high lake level following the rains.

Salvinia also occurs in Nairobi River, Lake Ol Bolossat, Ewaso Ngiro (north) River, Ewaso Narok River, Masinga Dam, Ramisi River and possibly in other aquatic ecosystems yet to be investigated.

Water hyacinth

Eichhornia crassipes (Martius) Solms-Laubach, commonly known as water hyacinth is a flowering plant belonging to the family Pontederiaceae. Its centre of origin is reported to be Amazonia, Brazil with natural spread to other areas of the South American continent (Harley, 1990). During the last 100 years, water hyacinth has spread to many tropical and subtropical regions of the world.

Water hyacinth appears to have been introduced to Egypt between 1879 and 1892 (Gopal and Sharma, 1981), South Africa in 1910 and Zaire in 1952 (Gopal, 1987). It also occurs in the Pangani River (Tanzania), Kafue River (Zambia), Upper Nile (the Sudd and Gebel Aulia Dam) and in Lake Mariut (Egypt) (pers. obs., 1980). The most recent serious outbreaks are in Nigeria (Oke *et al.*, 1988), Ivory Coast, Lake Chivero in Zimbabwe (Marshall, 1989) and Lake Victoria (Taylor, 1991).

Introduction of water hyacinth into Kenyan waters dates back to 1957 when it was first recorded as growing in ornamental ponds in Nairobi and Mombasa. It appeared in Lake Naivasha for the first time in 1988 and since then it has spread all round the lake sharing the littoral areas with salvinia.

Population increase of the water hyacinth is principally through the production of stolons bearing daughter plants but large quantities of long-lived seeds are also produced. Under favorable conditions, populations have been recorded as doubling every 5-15 days (Mitchell, 1978).

Water lettuce

Water lettuce or Nile cabbage *(Pistia stratiotes* L.) is a member of the family Araceae. It is of uncertain origin but has been used as a source of medicine for centuries. Pliny described its medicinal use in ancient Egypt in 77 AD while Chopra and others its use in India (cited in Sculthorpe, 1971, pp. 519-520). It is now one of the most widely distributed hydrophytes.

Population increase is through production of stolons bearing daughter plants. It occupies a similar habitat to that of both salvinia and water hyacinth. It is reported to have been more plentiful in the White Nile prior to the invasion of water hyacinth (Holm *et al.*, 1977).

Water lettuce is found in most freshwater ecosystems in the country. It occurs in Lake Naivasha (Njuguna, 1982) Lake Victoria (Njuguna *et al.*, 1985), Lake Baringo, Marsabit Forest, Shimba Hills (Mayo, 1985) and the Tana River Delta (Njuguna *et al.*, 1991). In these areas, water lettuce has not posed any problem but its luxuriant growth in the coastal areas of Kenya suggests that it is a potential threat to the coastal wetlands.

Control of floating aquatic weeds

There are three principal methods of controlling floating aquatic weeds - physical, chemical and biological. These three methods have been employed variously to control the floating aquatic weeds in Kenya.

Physical control of salvinia by manual removal and drainage has been used in Lake Naivasha and the Kitale areas, respectively, without success. Water hyacinth has been controlled in Nairobi by manual removal but it still thrives in ornamental ponds. Salvinia was controlled by aerial application of Gramoxone S, an aquatic herbicide, in Lake Naivasha in the mid-1960s and early 1970s, but salvinia infestations recurred after a period of a few months. In 1970, biological control of salvinia in Lake Naivasha was attempted using the grasshopper, *Paulina acuminata,* without success as the grasshopper failed to establish.

Generally, it has been found that the physical and chemical control methods of floating aquatic weeds are useful only for short-term control since growth is rapid and the methods often have to be repeated. It is also to be noted that chemical control, although useful, affects non-target plants and animals and thereby degrades the environment. Biological control, on the other hand, does provide an environmentally friendly, cost effective and permanent reduction of floating aquatic weeds.

A breakthrough in the control of salvinia has been achieved through the use of a small weevil, *Cyrtobagous salviniae,* collected in the native range of *S. molesta* in Brazil (Room *et al.*, 1981). The weevil has been used in Australia, Sri Lanka, India, Papua New Guinea, Namibia, Botswana, Zambia and South Africa. Recently *C. saliviniae* was released in Lake Naivasha, Kenya in May 1991 and its establishment has been confirmed (M. Cock, pers. comm.).

The control agents which have been most successful in the control of the water hyacinth are two weevils, *Neochetina bruchi* and *N. eichhorniae,* and the moth, *Sameodes albiguttalis*. The action of the two weevils appears complementary since a higher level of control has been achieved in USA and Sudan where both species have been established for several years. *Neochetina echhorniae* has now been released in South Africa, Zambia and Zimbabwe (Harley, 1991). In Australia, water hyacinth has been controlled by *N. echhorniae* (Delfosse, 1990).

Another weevil, *Neohydronomous affinis*, also from Brazil, has been used with success to control water lettuce in Australia, South Africa, Papua New Guinea, Zimbabwe and Botswana (Harley, 1990). In all the sites of release in Zimbabwe, plant population density and plant size declined following the introduction of *N. affinis* and substantial control was achieved in less than 12 months (Chikwenhere and Forno, 1991).

Conclusion

Biological control seems to be the most environmentally friendly and cost effective method of aquatic weed control, resulting in a permanent reduction in the expanse of the floating aquatic weeds. Host-specific agents for biological control of salvinia, water hyacinth and water lettuce have been found and their establishment in various parts of the world has led to the reduction of weed infestations to acceptable levels.

It is recommended that a national survey of the extent and nature of the aquatic weeds be undertaken as a matter of high priority. As soon as an infestation is confirmed, biological control should be implemented. Post-release studies on the biological control organisms which would include establishment, impact, environmental effects of biomass degradation and population dynamics should be conducted.

There is a need to promote public awareness on the problems of floating aquatic weeds and to develop an early warning system for new problems. Action should be taken to prevent the spread of weeds to new areas.

Finally, there is need for short-term, medium-term and long-term training in the disciplines of wetland ecology, weed science and limnology in order to effectively implement management strategies for floating aquatic weeds .

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Wetland conservation in Kenya: KWS and Ramsar

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Summary

The importance of wetlands in Kenya was first stated by the Kenya Government in its 1963 Manifesto on conservation of natural resources. In subsequent years, several areas have been designated as parks or reserves, for example Lake Nakuru National Park and Lake Bogoria National Reserve. Kenya ratified the Ramsar Convention in June 1990 and designated Lake Nakuru National Park as a Ramsar site. KWS is committed to conservation of natural resources and habitats.

Introduction

Wetlands are among the most productive life-supporting systems on earth and their conservation is important for biological, hydrological, economic and aesthetic reasons. Wetlands are very important as stop-over and wintering grounds for migratory birds, especially the palaearctic migrants (Curry-Lindahl, 1961).

Kenya Wildlife Service (KWS) has the mandate to conserve Kenya's natural resources, which include wetlands. This is important as water is essential for most wildlife. Appreciating the importance of wetlands world-wide and the threats facing them, Kenya ratified the Ramsar convention in 1990. KWS will play a key role in conservation and protection of wetlands as the managing authority of the Ramsar Convention.

The wetlands, especially Lakes Nakuru, Naivasha, Bogoria and Magadi, are famous for their spectacular avifauna and are economically and ecologically very important. Many wetlands in Kenya are threatened by human activities (Njuguna, 1985; Odero, 1985).

KWS policy on wetland conservation

Kenya's commitment towards conservation of natural resources, water and water catchment areas was explicitly stated in her 1963 Manifesto on conservation of natural resources. Kenya's natural resources were recognised as a priceless heritage for the future and the Kenyan Government thus pledged to conserve them for posterity, with all means at its disposal. In 1969, at the first Wildlife Conference for Eastern Africa, the need to conserve and protect natural resources, including wetlands, was noted (Brown, 1969).

A statement issued in 1987 at Regina, Canada, during the proceedings of the Third Conference of Contracting Parties to the Ramsar Convention, Kenya emphasised her commitment to conserve water catchment areas and wetlands. Kenya's wetlands were noted for their importance as migratory routes, as well as wintering areas for birds, for example the European White Stork.

One of the most important goals of Kenya Wildlife Service is to conserve the natural environment of Kenya, its fauna and flora and their habitats, for the benefit of mankind and as a world heritage (Government of Kenya, 1990). KWS is trying to conserve more of the under-represented habitat types, for example wetlands, for ecological, economic, aesthetic and scientific values.

Wildlife, as a natural, valuable and economic resource, is influenced by the complex relationships between land use, tourism, soil conservation, water and rural development (Government of Kenya, 1990). As water is very important to wildlife, the management of its catchments, conservation and associated human activities will need a bold new approach. Conservation of natural resources involves a balance of interests; it becomes a consideration of wise use choices and this can only be achieved through deliberate planning (Poore, 1970). Thus KWS will involve government departments concerned with water, fisheries, irrigation and hydropower in deliberate planning and decision making for the use of water and wetlands, in regard to the impact of these decisions on wildlife.

The Ramsar Convention and its implications for Kenya

The first Conference of the Convention on Wetlands of International Importance was held in Ramsar, Iran in 1971. The Convention is an intergovernmental treaty which provides a framework for international cooperation for conservation of wetland habitats.

Wetlands are rich in flora and fauna and thus are important ecosystems; they are very productive environments - over two thirds of world fish harvest is linked to the status of wetlands. The importance of wetlands all over the world is recognized as they are critical habitats for waterfowl. The chain of wetlands world-wide forms important habitats and wintering grounds for migratory bird species. At the same time wetlands are threatened by drainage, land reclamation, pollution, over exploitation and land degradation. Thus the broad objectives of the Ramsar Convention are to curb the loss of wetland habitats to ensure their conservation.

Kenya has established various parks and reserves which qualify as wetlands under the Ramsar Convention (see Table 1) and KWS will cooperate with the Ramsar Bureau to conserve wetlands and their associated species. There are particular justifications for conserving these areas. The Mzima Springs in Tsavo West National Park is part of an important catchment area. The Tana River Primate National Reserve is a floodplain wetland which depends on the flooding of the Tana River. It is the habitat for the endangered primates, the Tana River Red Colobus and the Tana River Crested Mangabey (Allaway, 1990). In Amboseli National Park, Lake Amboseli and associated swamps are dry season wildlife refuges (Thorsell *et al.*, 1981). As well as their scientific values, wetlands, such as Lakes Nakuru and Baringo, are important tourist areas for bird watching (Government of Kenya, 1990).

The Ramsar Convention came into force in 1975. In 1987, Kenya sent a delegation of observer status to the conference held in Regina, Canada. The concept of wise use was recognised and defined as the utilisation of wetlands while maintaining the natural properties of the ecosystems. It was against this background that Kenya ratified the convention in June 1990 in Montreux, Switzerland and Kenya became an Alternate Representative of the Standing Committee representing the African region. Kenya, as a contracting party, is under the obligations outlined as follows:

1. Wetland conservation should be included and given due consideration within national land use planning. The land use planning should be formulated and implemented so as to promote the wise use of wetlands within its territory;
2. designation of wetlands for inclusion in a list of wetlands of international importance;
3. the contracting party is to inform the convention bureau of any changes or likely changes in the ecological characters of the listed sites;
4. establishment of wetland nature reserves or parks;
5. training of personnel competent in wetland research and management must be undertaken to provide a professional working group.

Kenya has fulfilled some of these obligations and, in June 1990, selected Lake Nakuru National Park for inclusion in the list of wetlands of international importance.

Establishment of wetland nature reserves or parks

Kenya has national parks and reserves which are very important as wetlands (Table 1). The issue of land use and land use planning is paramount in wetland conservation. This should be pursued aggressively through a national committee or similar organ, composed of competent multi-disciplinary professionals, backed by a legal framework and with a time frame to implement various policies.

Table 1 Wetlands within conservation areas in Kenya

National Parks	Aberdares	A, B
	Amboseli	C
	Chyulu	D
	Kora	D
	Lake Nakuru	E
	Mount Elgon	A, B
	Mount Kenya	A, B
	Saiwa Swamp	C
	Mzima Springs	D
National Reserves	Boni	D
	Dodori	D
	Lake Bogoria	E
	Losai	D, G
	Tana River Primate	D
National Marine Reserves	Kiunga	G
	Watamu	G

Biotic communities

A Afro-alpine glacier and moorland
B Highland moist forest
C Permanent swamps
D Ground water, riverine forest or floodplain
E Alkaline lakes
F Grassland
G Mangroves

(Source: Government of Kenya, 1990, Annex 4)

Table 2 Future Ramsar sites and reason for suggestion

Conservation areas	Lake Amboseli	A, C, E, F
	Lake Bogoria	A, C, E
	Mzima Springs	A, C, E
	Tana River Delta	A, B, D, E
Non-conservation areas	Bura Irrigation Project	A, G
	Crater Lake - Naivasha	A, E, F, G
	Kano Plains - Lake Victoria	A, G
	Kiambere and Masinga Dams	A, G
	Lake Baringo	A, E
	Lake Elmentaita	A, E, F
	Lake Magadi	A, E
	Lake Naivasha	A, C, E
	Lake Ol Bollossat	A, E, G
	Lake Turkana	A, E, F
	Lake Victoria	A, D, E, F
	Lorian Swamps	A, C, E, F
	Tana Delta	A, B, C, D, E, F
	Yala Swamps	A, B, C, D, E

Reason for suggestion

A Bird life - especially waterfowl
B High biodiversity/endemism
C Water catchment/control
D Riverine forests
E Tourist values
F Special habitat
G Bird shooting - controlled

(Source: Government of Kenya, 1990, Annex 10)

The Ramsar site in Kenya

Lake Nakuru lies at 0°24'S and 36°05'E and at an altitude of 1,759 m above sea level in the Great Rift Valley. It has an area of 18,000 ha and is within a National Park. Lake Nakuru is bounded to the west by the Mau Escarpment and to the east by the Lion Hill Ranges. The lake has no outlet and is alkaline and saline. It is fed by the Enjoro, Enderit and Makalia Rivers and seasonal springs (Maskal, 1987)

The southern part of the lake was established as a bird sanctuary in 1960. In 1961 the cichlid, *Oreochromis alcalicus grahami*, was introduced and thereafter the diversity of fish-eating birds at the lake increased. In 1964 the whole lake was declared a bird sanctuary and Lake Nakuru National Park, with an area of 42 km^2, was gazetted in 1967. Expansion to the south of the lake in 1973 increased the park area to 170 km^2; Rothschild's Giraffes, from Soy in Western Kenya, were introduced in 1977. Lake Nakuru National Park was established as the first Kenyan rhinoceros sanctuary in 1987, after erection of an electric fence which surrounds the entire park.

The lake is a spectacular avifauna site; flamingos, pelicans and waders are found in large numbers. The chief source of food (*Spirulina plantensis*) for Lesser Flamingos is abundant. Waterbucks, lions, leopards, impalas and buffaloes are other animals of interest in the park. KWS is charged with the responsibility of managing all aspects of the park, for current and future generations. Substantial revenue is generated through gate collections and camping fees.

The maintenance of ecological processes in the lake is threatened by pollution from Nakuru town. Industrial effluents, sewage and agricultural wastes from the surrounding areas find their way to the lake. An integrated land use policy for the lake catchment is needed to protect the lake.

Future Ramsar sites

Some wetlands within and outside the conservation areas are suitable as Ramsar sites as they are important wetlands for avifauna (see Table 2). Research should be undertaken to determine their suitability as Ramsar sites.

Threats to Kenya's wetlands

Kenya's wetlands are under threat from pollution, siltation, reclamation, pesticides, damming and other human activities. These must be controlled if the loss of the wetland resource is to be prevented (Moore, 1970; Njuguna, 1985; Odero, 1985).

The introduction of Nile Perch (*Lates niloticus*) to Lake Victoria in 1958 was an economic, as well as an ecological, disaster as it resulted in drastic reduction of fish diversity (Watson, 1989). The home of the endangered Tana River Red Colobus and the Tana River Crested Mangabey, the Tana River Primate National

Reserve, is threatened as the riverine forest is affected by damming in the upper catchment (Allaway, 1990). *Salvinia molesta* is a serious threat to Lake Naivasha. Laws to protect wetlands outside and within protected areas are currently not enforced.

Recommendations

1. Establishment of a national wetlands policy.
2. A wise use concept, according to the Ramsar Convention, should be adopted for lake and river drainage basins.
3. An inventory of wetlands and their current status should be established.
4. Development and conservation should be integrated to enhance wise use of wetlands on a sustainable basis.
5. Research on wetlands should be encouraged and used by land use planners.
6. Competent personnel should be trained to manage wetlands.
7. Collaboration of KWS with national and international organisations, non-governmental organisations, Ramsar and other wetland conservation organisations should be encouraged and strengthened.

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The sociological and economic values of Kenya's wetlands

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Summary

The historical associations between people and wetlands should be taken into account in development planning. The traditional benefits which people have drawn from wetlands include social, cultural and economic activities. It is noted that the rapid rise in human population has resulted in land scarcity, forcing land users to clear wetland vegetation for crop farming. This is threatening the future existence of these diverse ecosystems. Alternative strategies which involve the people in the conservation of wetlands are possible.

To predict future trends in the utilisation of wetlands, their traditional uses and the changing socio-economic factors that are forcing the non-traditional use of wetlands must all be understood.

Introduction

Kenya's wetlands, covering 14,000 km^2, are a resource of great social-cultural and economic potential (Gichuki, 1990). Many of Kenya's rural communities draw food, medicinal products, fuelwood, materials for building and handicraft from wetlands. However, these ecosystems are today facing a serious threat to their continued existence from encroaching human development activities, especially agricultural operations. Unfortunately, most research projects and case studies on wetlands in Kenya are contributed by biological scientists (Njuguna, 1982) with a bias towards the technical aspects of the function and value of wetlands and not the people who draw benefits from or suffer due to their presence. There is no contribution from social scientists and no fruitful recommendations have been given on how best to incorporate land users into the management and conservation of wetlands. The physical wetland products may be directly or indirectly consumed, but social-cultural benefits cannot be readily quantified. People have historical and current associations with wetlands.

Acknowledging the fact that the spatial distribution of wetlands in this country is uneven and that they are utilised by several communities with different social-cultural backgrounds, the Western Kenya region, specifically the Nzoia River basin, has been selected for a detailed investigation in this paper (see Figure 1). The Nzoia River and its tributaries pass through Trans Nzoia, Uasin Gishu, Bungoma, Kakamega, Siaya and Busia Districts and finally drain into Lake Victoria. Economic and social activities along this basin are a reflection of the mode of life of several ethnic groups, with the Luos and the Luhyas in the majority. This discussion is based mainly on these two groups.

The people's historical association with wetlands

The life, culture and history of the people living in or near wetlands have to some degree been influenced by the presence of, and interaction with, those diverse ecosystems. Whether hunter-gatherers or traditional fishermen, there were always useful resources that were drawn from the wetlands to satisfy certain ceremonial requirements, handicraft industrial inputs, medicine, clean water and food. The following sections discuss in detail some of the known historical associations of people and wetlands.

Sites of special cultural value in the wetlands

It is a widely held view that the traditional African land use systems encouraged land use practices that undermined the ecological bases of their survival by engaging in extensive shifting cultivation and overgrazing on common lands. However, there were also cultural practices that served conservation needs. Among the Bukusu and other sub-groups of the Luhya people, the circumcision ceremony was and still is a highly important social and cultural event. As the young males are being prepared for the initiation into adulthood, adequate arrangements are made to ensure their successful transition into the new life as responsible people. The most important of these is the identification of the 'sacred places' at which the occasion is celebrated.

The ceremony takes place in special sites in wetlands. The criteria adopted in the choice of a site includes privacy and presence of ample water and mud. It must, therefore, be well covered with dense wetland vegetation. At the onset of the ceremony, the Bukusu youths are taken to this sacred site, where they smear themselves thoroughly with mud, and then walk naked back home. There are two symbolic meanings attached to this: firstly the soil gives protection similar to that of the mother's womb - keeping the young man warm as he undergoes the ceremony; secondly this is the last time that the young man is expected by the society ever to go naked as he has been initiated into responsible manhood.

It is important to note that this muddy soil is found only in some places in the wetlands. The traditional beliefs about these sites, in line with the traditional needs

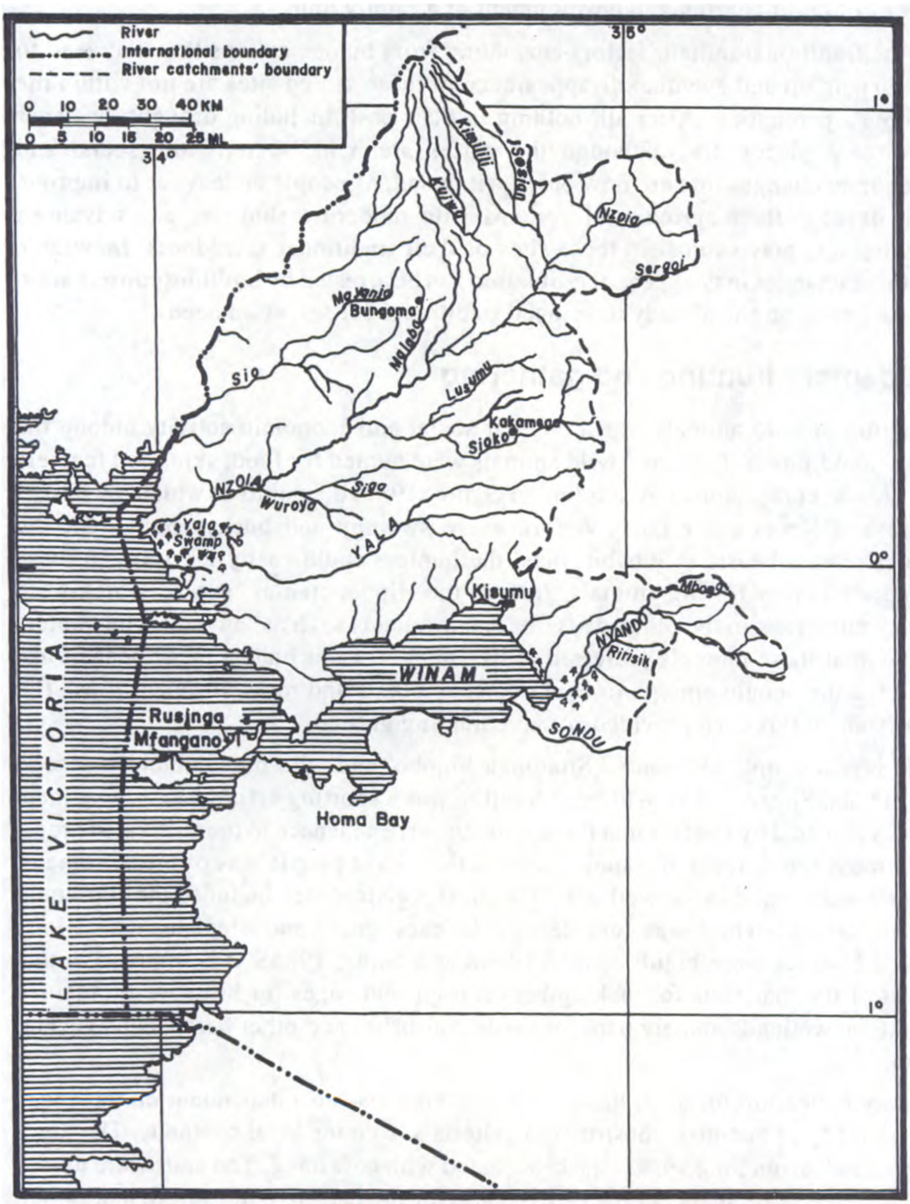

Figure 1 The River Nzoia drainage basin and other drainage systems of Lake Victoria

for their conservation, is that they should never be allowed to dry up or lose their basic characteristics. If the site dries up, it is believed that the generation of young men who 'bathed' at that site may not survive to fulfil their biological and societal duties of child-bearing and development of a family unit.

In the traditional milieu, factors emanating from human actions that may lead to the drying up and eventual disappearance of these sacred sites are not within the people's perception. After all, nothing in their past, including drought, has ever left these places dry. Although the places are held 'sacred', the social and economic changes that are now being witnessed, as people endeavour to improve and develop their agricultural systems with modern techniques and advanced technology, may soon strip these sites of their traditional sacredness. Inevitable as these changes may appear, the situation can be arrested by building conservation strategies upon the already developed traditional conservation needs.

Sedentary hunting and gathering

Hunting of wild animals was a popular social and economic activity among the Luos and Luhyas. Birds and wild animals were hunted for food, skins and feathers (O. Abok, pers. comm.). According to Ogutu (1987) the points at which the Rivers Yala and Nzoia enter Lake Victoria were swampy and bushy enough for the water-related beasts to inhabit, thus, the hunters could easily lay traps in these concealed areas for big animals, such as the Hippopotamus 'rawo' (which were fairly numerous in the olden days), or small rodents such as 'anyier'. The hunters knew that these animals preferred to live next to water bodies on or near farms, whence they could emerge to feed on maize plants and roots of other crops. The wetlands in this case provided suitable hunting grounds.

The Nyala people too hunted Sitatunga 'injobe' and wild pig 'imbichi' for food (Were and Soper, 1986). Although hunting was a sporting activity for young men, it was justified by the fact that these animals were a menace to the cultivated crops. The most active form of trapping among the Luhya people was of birds, some of which were found in the wetlands. The most popular catch included the Harlequin Quail 'isindu', which was considered a delicacy, ducks and whydahs, whose long tailed feathers were highly valued (Were and Soper, 1986). It is impressive that most of the materials for making basket traps and cages for birds were obtained from the wetlands namely papyrus reeds, bulrushes and other herbaceous vegetation.

Honey collection for local brews and medicine was also dependent on the cheap availability of bee-hive construction materials from the local wetlands. The hives were made from long wicker baskets coated with cow dung. The ends were closed with coiled grass mats, with a central hole for the bees to enter (Were and Soper, 1986). Today bee-farming is a lucrative business in the area.

Vegetables and fruits

To supplement the supply of cultivated vegetables, the Luo women gathered wild greens especially during the dry seasons; some wild greens were gathered irrespective of the season due to their delicacy and popularity (Ogutu, 1987). The Luhya people collected wild greens known locally as 'enderema' and 'lubiliabilia' from the wetlands. These plants were also used to cure certain ailments of the stomach. The fact that land was commonly owned meant that one could collect fruits and vegetables that grew on wetlands without restriction. The changing land ownership system that encourages privatisation of land has somehow reduced the importance of gathering wild greens.

Building materials for traditional houses and artifacts

Clay is a wetland product with a long history of economic and social-cultural importance. In building construction, clay of different types was used for plastering the walls and floors of houses (Odak, 1987). The clays varied depending on the local availability but those obtained from wetlands were usually preferred (O. Abok, pers. comm.). Such clays have also been used extensively in providing commodities such as pots of different types and sizes and smoking pipes (Odak, 1987).

The herbaceous vegetation from the marshes was harvested with the clay and used in the construction of houses and granaries. Traditional Luhya houses, for example, had walls constructed from a framework of sticks or reeds and the roof was assembled separately from reeds or maize stalks tied to rings of grass or split palm leaves (Were and Soper, 1986).

Basketry is another important, traditional industry that depends on the availability of twigs and grass (Odak, 1987). Mat-making is a popular art among the Luo people living in or near wetlands (O. Abok, pers. comm.). The popular 'marachi' sofas are made from 'amaduru' reeds and branches of the 'isiola' tree. They are often coloured with natural black and yellow dyes made from the water plant 'litodo' (Were and Soper, 1986).

Extraction of house construction materials from the wetlands is likely to continue in the future with slight modification as better technology is acquired. Although the traditional grass-thatch is slowly being replaced by corrugated-iron sheets, the former is likely to be the only source of roofing materials for poor farming families. Unfortunately, sources of traditional thatch are becoming scarce due to over-exploitation and lack of replacement. Therefore, there is an urgent need to encourage sustainable exploitation of these resources.

Traditional fishing industry

Fishing has always been a major occupation of the people living along the Nzoia, Yala, Nyando, Sondu and Sio Rivers and their tributaries. Most of the fishermen along these rivers are involved in fishing for domestic consumption and local sales. In the traditional setting, the wetlands were utilised not only as fishing grounds but also as essential sources of the raw materials used in the making of fishing equipment. The conical basket traps, 'esivu' and 'omukono', used by the Luhya people, were woven from reeds arranged in hexagonal patterns. Another fish trap 'olukhwiro' consists of a fence of close set reeds tied together with papyrus stems and fastened to posts in a complex pattern (Were and Soper, 1986). The traditional Luo fishermen also used various methods for catching fish using baskets and traps made from papyrus stems or reeds. The basket trap 'sienya' was made of reeds fastened together longitudinally (Ogutu, 1987). It is possible that a number of people derived their livelihood out of making fish traps and baskets from raw materials harvested from the wetlands.

The livestock economy

Livestock grazing in wetlands was, and still is, a common practice for many communities in Kenya. The only notable difference today is that the social control systems that ensured sustainable utilisation of these resources are slowly disintegrating.

The Njemps/Tugen people living around Loboi/Kesubo Swamps are an example of a people who have through generations maintained a socially acceptable system of 'wise use' of wetlands. The wetlands are used for dry season grazing only; at the onset of the rains, the people and their animals move away from the wetlands to other areas for grazing and will only return when the dry season starts. A council of elders is vested with the authority to decide when to start grazing in the wetlands again; the grazing is patterned in such way that overgrazing is minimized (W. Kimosop, pers. comm.).

In other parts of Kenya, especially in the Nzoia River basin, the social systems that helped to regulate the use of resources are declining; decisions formerly made by a council of elders are left to individual land-owners. This has as much to do with the changing land-tenure systems as with the immigration and emigration of people in these areas.

Modernisation and the changing uses of wetlands

Western religions, education and health facilities have contributed much to changing the traditional belief systems and their inherent resource conservation traits. The new religions encouraged people to destroy sacred instruments, which then gave people the courage to attack sacred places as well. Modern health facilities are preferred to the herbs and the secluded places of circumcision in wetlands (T. Kuria, pers. comm.).

These forces of modernisation have also changed the traditional architecture. Shapes and sizes of houses are slowly changing from round huts to modern rectangular houses with many rooms: a move away from a grass-thatched house to a brick-walled, iron-roofed house is seen to carry status and is a sign of development. The importance of harvestable wetland vegetation in house construction is declining as a result.

Modern farming techniques have introduced exotic vegetables which have replaced the traditional ones. Sources of wild greens in the wetlands are slowly being replaced by areas of cultivated vegetables. Observations of farming activities along the Nzoia River basin showed that crop farming and cattle grazing in the wetlands is contributing handsomely to the development of the local economy. This is the only belt where people can grow irrigated crops of maize and vegetables all year round. Maize grown during the dry season has a ready market in urban centres where the demand for green maize appears insatiable.

The maize stalks, along with a constant supply of water and salt-licks from wetlands, support a fast-growing livestock economy. The raw clay is today supporting a healthy brick-making industry. All these economic gains contribute to and justify further drainage of wetlands.

The situation is exacerbated by the fast-growing human population in Kenya, estimated at 4.1% per annum (Government of Kenya, 1986), coupled with restricted outlets for emigration. This means that the local populations have used most available land (Were and Soper, 1986). The growing population exerts enormous pressure on the available land as land subdivisions and intensification continues, thus cultivation and grazing are extended to environmentally sensitive areas such as hill slopes and wetlands.

There has not been enough awareness generated of conservation issues; for instance the laws restricting cultivation on river banks have not been strictly observed, more so on private lands. To the land-owner, no law is seen to be broken when he clears a 'weed' that prevents him from extending his farming activities.

Conservationists, desperate at their inability to reverse this dynamic situation, have emphasized the strengthening of the laws governing the protection of these fragile ecosystems. In defence of these valuable habitats, Gichuki (1990) was of the opinion that loss of agricultural land in the basin might be a better way of confronting reality than waiting for the extermination of local wildlife resources. No sympathy is shown by the conservationist to the land owner who has degraded his only source of survival - a piece of land. Farmers, having been denied the use of their land, will look covetously on those areas denied to them by conservation laws (Ecosystems, 1982). Consequently, the land use conflicts intensify, while illicit clearing of wetland vegetation and hunting continues.

Conclusion and recommendations

Kenya's wetlands are one of the nation's important resources for social-cultural and economic development, however, due to high population growth rates, these resources are being over-exploited. Many patches of wetlands, especially along the Nzoia River basin, have now lost many of their original characteristics. This means, therefore, that some of the social, cultural and economic activities that are dependent on wetlands cannot be maintained and underlines an urgent need for the formulation of policies and programmes to address wetland conservation.

In view of the fact that most patches of wetlands of western Kenya border, or are found on, private lands, actions that incorporate and solicit participation of the land-owners in future wetland conservation programmes are a prerequisite to success. According to Chavangi (1985) intervention programmes that do not take into consideration the local cultural backgrounds, beliefs and traditions of the communities are likely to fail. The lack of success is often due to the implementing agency's concern for technical issues with disregard of the local people's opinions. Therefore understanding the people's perceptions and attitudes is critical in developing any sound wetlands conservation programme (Gichuki, 1990). Changing the people's attitude towards wetland conservation is also an important dimension. There is need to expand community education programmes to incorporate conservation education (Ecosystems, 1982). It must, however, be an enabling education which allows the people to identify their problems and hence seek desirable solutions that are acceptable and appropriate to their cultural setting (Chavangi, 1985). In addition, farmers should be encouraged, through increased support of extension services and provision of farm inputs, to improve overall farm crop production. This will minimize the present concentration of farming activities on those attractive productive areas in the wetlands.

More research is also needed, not only on the socio-economic but also on technical aspects of utilisation of wetland products that will lead to sustainable use. Economically beneficial uses, coupled with education to ensure that conservation becomes an instinct, not a forced activity on the part of the land users, must be found.

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Plant products from freshwater wetlands

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Introduction

Wetlands have played a significant role in man's civilization; the floodplain of the lower Nile valley and delta have supported large human populations for 6,000 years while the swamps associated with complex fishpond ecosystems in Czechoslovakia have been under human management since the 13th century AD. Today the agricultural wetlands colonized by the domesticated reed swamp grass, rice (*Oryza sativa*), feed more than half of the world's human population.

Aquatic macrophytes in freshwater wetlands are increasingly being recognized as the most productive plant communities (Westlake, 1975; Thompson *et al.*, 1979; Muthuri *et al.*, 1989). Although they cover only 1% of the land surface they contribute as much as 5% of the total primary production. One of the most common freshwater macrophytes in Africa, papyrus (*Cyperus papyrus*), has been shown to be among the most productive plants with dry matter production rates in excess of 6,000 g/m^2/year (Muthuri, 1985). Due to high rates of production the biomass reserve of freshwater wetlands presents an enormous potential for exploitation on a sustainable basis. These wetlands provide food for human society and export nutrients to adjacent water bodies. In addition, they can be exploited for pulp, paper and board production, for building purposes and for energy production.

Food production

Wetlands, due to their high productivity, can make significant contributions to human food supplies. During the dry season, African wetlands are used extensively for livestock grazing. Cattle follow the flush of grass growth on the drawdown zones and, as the plains around wetlands dry out, cattle wade into permanent swamps to graze on wetland plants such as *Phragmites, Echinochloa, Vossia* and *Panicum* (Howard-Williams, 1973).

In Kenya, papyrus and other *Cyperus* has been found to have some grazing potential and could be used as fodder in the dry season when other forage is scarce and of low nutritive value (Muthuri and Kinyamario, 1989). When chopped into small pieces and treated with urea phosphate, papyrus was voluntarily eaten by cattle (Hakanen, 1984).

Nutrient export

The productivity of freshwater wetlands has a significant impact on the adjacent water bodies. Wetlands are detritus-based ecosystems; biomass decomposes and the accumulated detritus, in the form of sludge, may be washed downstream and out of the swamp (Gaudet, 1976). This serves to enrich the downstream ecosystems with nutrients which act as a valuable food source for zooplankton, fish and the benthos. Thus, swamp-lake and swamp-river interfaces have been reported as areas of rich fishery potential in Africa (Beadle, 1981; Welcomme, 1972).

Paper making

For more than 5,000 years papyrus provided the principal writing material in much of the ancient world. Papyrus paper manufacture was an important industry in ancient Egypt; the pharaohs collected tax from the paper industry and hence the process of paper making was kept secret.

The Egyptian method of manufacturing papyrus paper was practised until 10th century AD. Today, Dr Hassan Ragab, the director of the Papyrus Institute in Cairo, has succeeded in producing papyrus sheets very similar in quality to those manufactured by ancient Egyptians (Jones, 1983), according to the following method. First the culm is cut into manageable lengths and the outer skin is stripped off to expose the pith. The strips are laid side by side on a smooth hard surface and a second layer is placed on top of and at right angles to the bottom layer. The two layers are then welded together by the application of pressure.

The use of swamps as a source of paper pulp remains largely unexploited. In 1914 a German paper pulp factory was under construction on the shores of Lake No in Sudan but was never completed (Thompson, 1976). In some parts of the world such as Rumania, reeds are used to manufacture paper.

Fibreboard

In Uganda in the 1930s, a firm called Fybro produced cardboard from papyrus in a factory near Kampala but later went into liquidation. More recently a small factory near Zaza in Rwanda has been manufacturing quality soft board for ceilings and roof and wall linings. This factory seems to be economically viable but is unlikely to exploit the potential offered by the large papyrus reserves in tropical swamps.

Building material

Wetland macrophytes, such as papyrus, were important in boat-building in ancient Egypt. Papyrus boats, called 'tankwas' in Amharic, are made from bundles of papyrus tied together with ropes and are still used today in Ethiopia by Waito fishermen on Lake Tana (J.J. Gaudet, pers. comm.). Thor Heyerdahl proved that larger papyrus boats were capable of sailing across the ocean between Africa and South America and suggested a link between Egypt and early Inca civilization.

Today papyrus is commonly used as a building material for houses; the dried culms are bound alongside each other to form screens which can be conveniently rolled up for transport. The screens are used as non-structural walls, partitions, ceilings and fences. Densely packed mats of culms can be used as roofing material.

Energy sources

The rapid disappearance of fuelwoods in many developing countries and the high price of oil has stimulated investigations into the use of wetlands as a source of energy. As early as 1914, a company was formed to use papyrus peat for fuel in Sudan. The company was called Suss Fuel Limited and the peat was called 'Suddite' in reference to the great 'Sudd' swamp on the Nile.

In the valley swamps of Uganda, Rwanda and Burundi there are deposits of peat built up over many centuries from decomposing wetland vegetation. At present peat is being harvested at Busoro in Rwanda. Peat is harvested in strips going out from dryland into the swamp edge and involves cutting out the plant cover and piling it to provide a working platform. The underlying peat is then cut down to a depth of about one metre with shovels and transported to the shore where it is dried.

The feasibility of using papyrus plant material as a source of fuel has been investigated (Anonymous, 1984). Papyrus culms are chopped into small pieces and air dried before being compressed into a briquette, 1/20th of its original volume. Machines similar to those used in producing briquettes from waste straw and wood chippings are used. The resulting fuel produces relatively little smoke on burning, has a low ash content and is relatively inexpensive to produce, compared with charcoal.

Results of exploitation

From the above discussion it is evident that wetland plants have great economic potential. Exploitation of this potential may eventually lead to profound ecological effects on these systems. Most significant in this respect will probably be the loss of large quantities of nutrients that would otherwise be recycled in the ecosystem. Harvesting of wetland plants will destroy the canopy structure and consequently interfere with light and temperature regimes and hence the microclimate of the wetland. This may eventually reduce wetland productivity and the quality of the harvestable material. For example, following a papyrus harvest in Lake Naivasha culm density increased to higher levels than those of undisturbed stands, but were shorter and thinner than the culms of the undisturbed papyrus (Muthuri, 1985). In addition the ceiling yield of the regrowing stands was lower (even after one year of regrowth) than the above ground biomass of the undisturbed stands. Clearly the effect of continued harvesting and other forms of exploitation requires further investigation.

Conclusion

In order to maintain high yields and a healthy environment in freshwater wetlands, suitable management programmes must be developed. However, these must be based on a clear understanding of the ecology of the wetland, hence the need for more research in these valuable ecosystems.

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Coastal wetland utilisation

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Summary

Coastal wetlands such as mangroves, seagrass beds and coral reefs are among the most productive and diverse biological systems on earth. They are places where marine, freshwater and land ecosystems meet and interact; where sediments are collected, water is purified, nutrients are recycled and the life cycle of a large number of plants and animals is acted out. While some coastal areas have been protected in marine national parks and reserves, many wetland areas have been reclaimed for farmland and for urban and tourist developments. Poorly understood and undervalued, some have been used as rubbish dumps and as drains for sewage effluents and toxic wastes.

In Kenya, coastal wetlands are of paramount economic, social and conservation value. They provide indispensable nursery and feeding habitats for commercially important marine organisms as well as exploitable natural products. They form crucial resting and feeding grounds for resident and migratory birds and provide opportunities for recreation and education.

Coastal wetlands have an important function in the stabilization and rehabilitation of the coastline. These ecosystems are interlinked and are very vulnerable to careless human exploitation. Sustainable multi-use management will require a greater knowledge of the complex ecological interactions. The future of coastal wetlands will depend on a cooperative effort between policy makers, scientists and users for the rehabilitation, conservation and management of this natural heritage. Growing concern for these ecosystems is shown by the increasing number of research studies incorporating collaboration with wildlife departments.

Introduction

Coastal wetlands have been given particular attention during the past decade. As areas of transition between land and sea, they are influenced by both marine and terrestrial systems, forming continuous gradients of influence. These open systems are among the world's most diverse and productive biotopes but also the most endangered ones. They are located at the margin between deep water and terrestrial uplands and in any definition the upper and lower limits of wetland areas are arbitrary boundaries (Chapman, 1977; Mitsch and Gosselink, 1986). A precise definition of coastal wetlands has not yet been developed as it depends on the objectives and interests of the users. Coastal wetlands are distinguished by the interplay between land and water, the presence of standing water, unique soils and vegetation and endemic fauna (Williams, 1990). Based on the definition of the Ramsar Convention on Wetlands in 1971 (see Defenition and overview), Kenya has a wide area of coastal wetlands which includes mangroves, seagrass beds and coral reefs.

Concern for the preservation of the marine environment in Kenya is demonstrated by the establishment of the following protected areas, with a total area of 850 km^2: Kisite National Park, Mpunguti National Reserve, Mombasa National Park and Reserve, Malindi and Watamu National Parks and Reserves, and Kiunga National Reserve (Figure 1) (Wells, 1988).

Kenya's coastal wetlands are of paramount ecological and economical importance. They yield large amounts of fish, crustaceans and shellfish and are valuable sources of other natural products (Saenger *et al.*, 1983; UNEP, 1982a, 1984a,b and 1985a). They also provide important recreation areas for tourism (Schoorl and Visser, 1991) and educational resources (UNESCO, 1979 and 1981). Their non-marketable value is of equal importance, i.e. stabilization of the coastline and the potential for rehabilitating degraded coastal areas.

Several studies in the last decade have identified environmental problems in the Kenyan coastal zone and expressed alarm at its ever increasing degradation (UNEP, 1982a-d, 1984a and b, 1985a and b, 1989; Government of Kenya (GOK), 1984 and 1985; McClanahan, 1987; Samoilys, 1988; Bess, 1990; Bryceson, 1990; IUCN, 1990; Jaccarini and Martens 1990 and 1991). However, the lack of knowledge of the complex ecological interactions, and of the effects of uncontrolled human exploitation, hampers adequate sustainable utilisation and management of these ecosystems (Saenger *et al.*, 1983).

Kenya's mangroves, seagrass meadows and coral reefs will be discussed in terms of their characteristics, occurrence, values and threats.

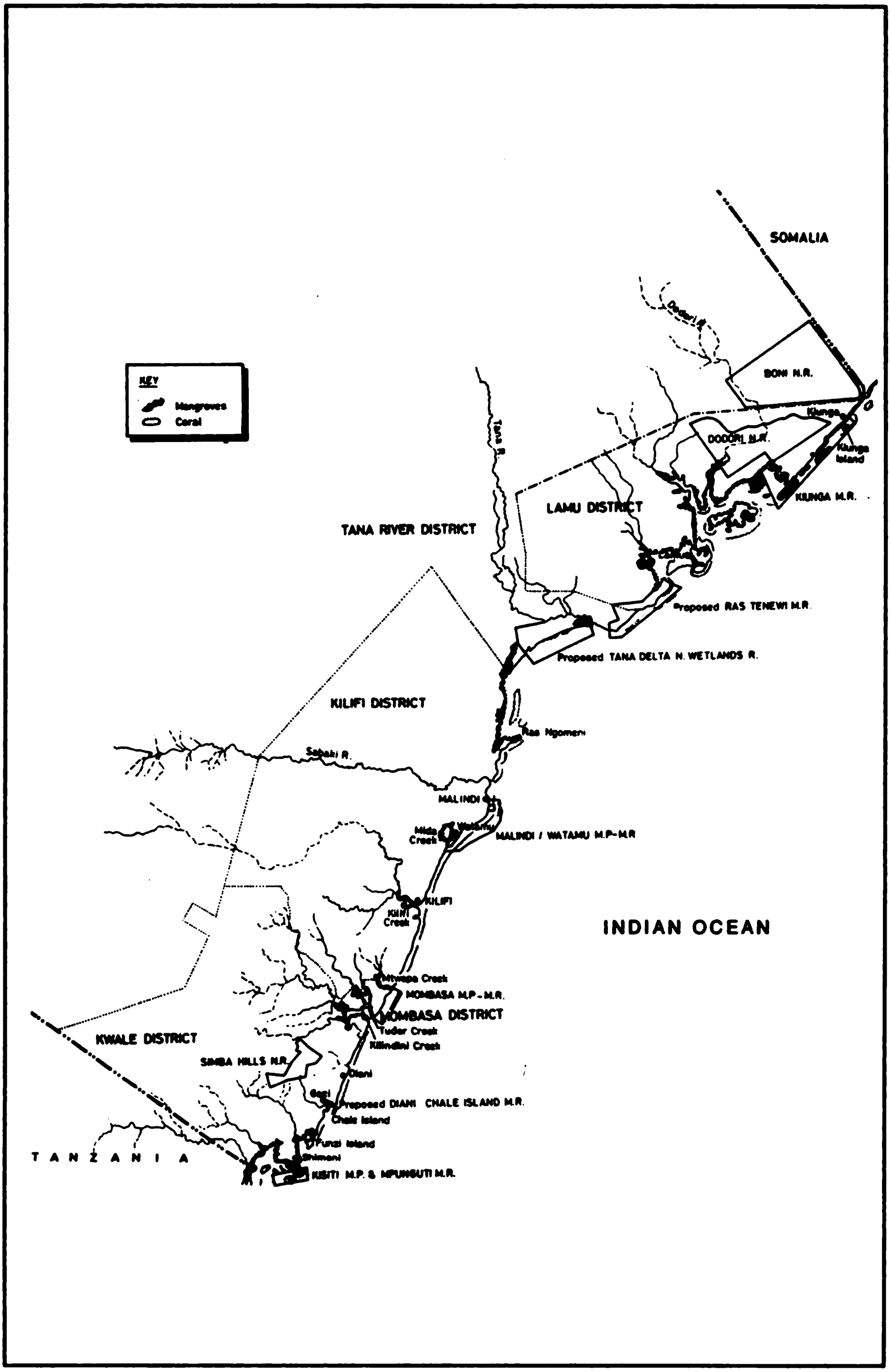

Figure 1 Coastal wetland utilisation

Mangroves

Description and occurrence

Mangroves are the evergreen trees and shrubs growing in sheltered tidal waters below the high-water level of spring tides; the mangrove community is referred to as 'mangal' (Macnae, 1968; Chapman, 1976). Mangroves have evolved characteristics which allow them to grow in a harsh environment where few other plants can survive. In addition to tolerating oxygen-depleted soils that accumulate reduced compounds, such as organic acids, ferrous iron and hydrogen sulphide, they must adapt to salt concentrations far exceeding the tolerance of most land plants. To meet the stresses of the intertidal environment, mangroves have developed a unique set of adaptations; these include aerial roots (pneumatophores, prop and cable roots) that absorb atmospheric oxygen as well as provide anchorage in the unstable substratum, the ability of salt exclusion or salt excretion, tissue succulence for retaining water and viviparity in the form of propagules which germinate while still on the parent tree (Macnae, 1968; Lugo and Snedaker, 1974; Chapman, 1976). For optimal development, mangroves require fresh water from a permanent or seasonal river or seepage.

The Kenyan mangrove forest is shown in Figure 1. It occurs in patches along the coast, around coastal islands (Mombasa and Lamu) and along the banks of coastal rivers (Tana and Ramisi) and creeks (Mida, Kilifi and Mtwapa). These mangrove formations extend over 52,980 ha with 33,500 ha being located in Lamu District (Doute *et al.*, 1981; GOK, 1983). Nine mangrove species have been identified showing a zonation that is influenced by soil composition, salinity and range and duration of tidal flooding (Isaac and Isaac, 1968; Macnae, 1968; Chapman, 1976; Moorjani, 1977; Ruwa and Polk, 1986; Gallin *et al.*, 1989; Beeckman *et al.*, 1990; Gang and Agatsiva, 1990; Ruwa, 1990b).

The most common species are *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera gymnorhiza*, *Sonneratia alba* and *Avicennia marina* (GOK, 1983). It is difficult to ascertain the potential production of these forests as little is known about the actual growing stock, vegetation composition and yield of mangrove forests in Kenya. The dynamics within a mangal - its species diversity and composition, nutrient recycling, seasonalities and interactions with adjacent biotopes - are being studied in Tudor and Gazi Creeks (Figure 1) (KBP, 1986-1991; EEC, 1991).

The mangal is a very productive and dynamic ecosystem with a continuous process of erosion and accretion. Its average gross primary productivity ranges from 2,300-5,074 g C/m^2/year (UNEP, 1985b). Mangrove leaves are the base of a detritus food chain supporting large numbers of fish, crustaceans and shellfish (Figure 2) (Nzioka, 1984; Ntiba, 1986; Little *et al.*, 1988; Kasyi *et al.*, 1990; KBP, 1986-1991;). The mangal root system offers substrates for algae (De Schrijver, 1990), sponges, tunicates, anemones, barnacles and oysters (Ruwa, 1990a; Tack, 1990) and provides shelter for many mobile animals. The roots trap sediments and break the force of waves, protecting the shoreline from erosion. Mudskippers and fiddler crabs (*Uca*) are typically found on the mudflats (Muya and Martens, 1990;

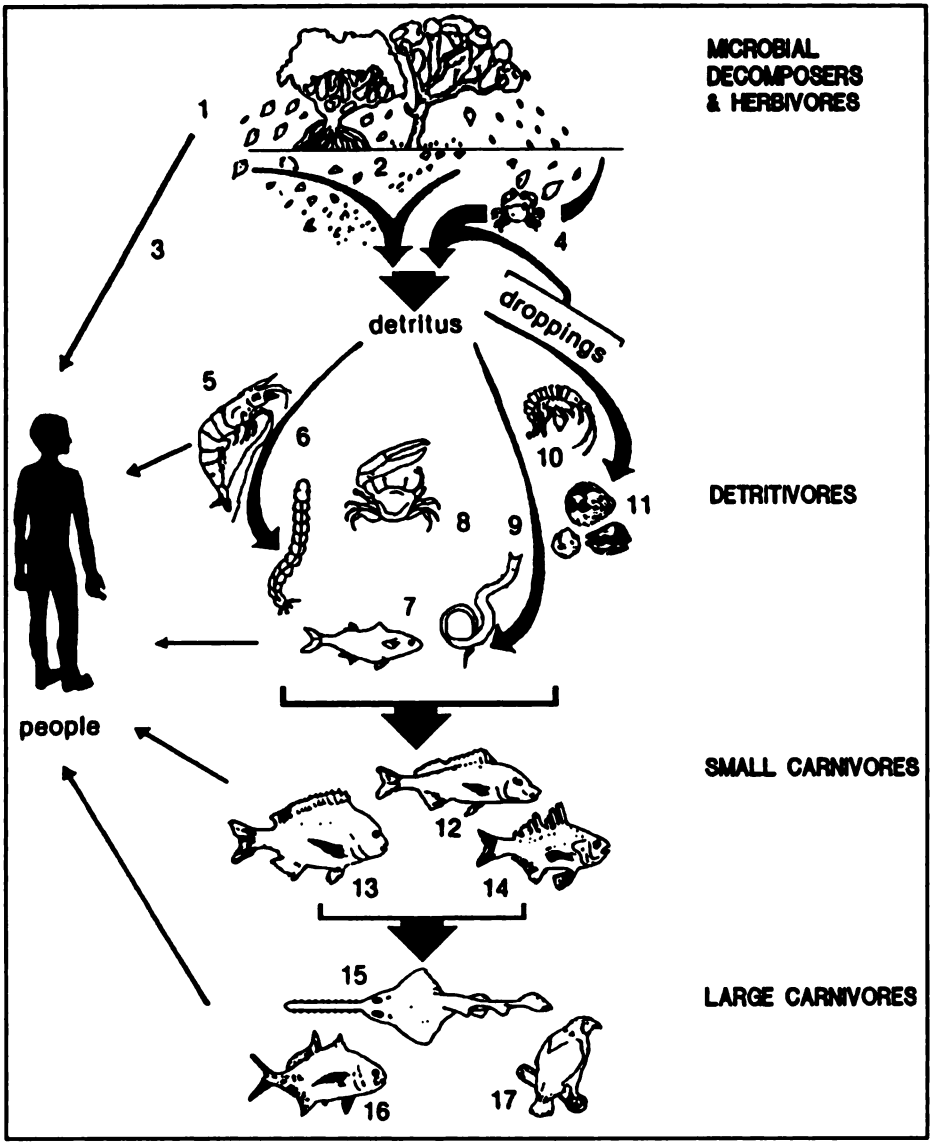

Figure 2 Ecological relationships within the mangrove environment (after Berjak *et al.*, 1977)

1 leaves
2 algae
3 fungi, protozoa, bacteria
4 sesarmid and grapsid crabs
5 shrimps
6 insect larvae
7 mullet
8 fiddler crabs
9 worms
10 amphipods
11 bivalve molluscs
12 grunters
13 emperors
14 pony fishes
15 sawfish
16 trevallies
17 sea eagle

Oluoch, 1990; Ruwa, 1990b), while green algal mats (*Caulerpa, Halimeda*), with associated animals such as amphipods and gastropods, are found exposed during low tide (Rutzler and Feller, 1988). Seagrasses occur in patches on the submerged mangal (De Wit, 1988; De Pauw, 1990; Coppejans, 1990).

The large amounts of seagrass leaves and drifting algae brought into the mangrove ecosystem at spring tides are an important addition to the detritus resource of the food chain. The above-water fauna includes mammals, birds, reptiles, molluscs and arthropods.

Values and utilisation

Ecological

Mangroves efficiently trap runoff sediments, hence preventing siltation of adjacent seagrass beds and coral reefs, and possibly promoting land-accretion. The tangle of their root system breaks wave action, thus preventing erosion of the shore line. Mangroves act as a buffer for water pollution by trapping pollutants from runoff waters. They provide indispensable nursery and feeding grounds for numerous species and are important wildlife sanctuaries.

Economical

Mangrove tree resources

Important genera used for timber, as posts, poles, roofs, fences and furniture, are *Rhizophora, Bruguiera* and *Ceriops*. Traditionally and today the main use of mangrove timber in Kenya is in house construction for the coastal people, due to its strength and durability; poles range in diameter from 2.5-14.0 cm. Mangrove poles have been exported in the past, particularly to Arab countries; when this was banned in 1982 a remarkable decline in the exploitation of mangrove forests occurred, especially in Lamu. A recent and extensive use of mangrove poles has been in the construction of tourist hotels and restaurants.

Mangrove trees, especially *Avicennia*, produce high quality charcoal and good firewood, thus the main cause of mangrove depletion near villages is for domestic cooking. The Kenya Calcium Products factory in Waa (Kwale District) uses firewood for the production of lime; since June 1990 the exclusive source of firewood is the mangrove forests of Gazi and Funzi Bay.

Sonneratia trunks are used for boat-building and the large pneumatophores are used as floats for fishing nets. The bark of *Rhizophora, Bruguiera* and *Ceriops* was once an important resource for tannin production (S.A. Robertson, pers. comm.) but today it is only used locally due to competition from wattle bark. Tannin has insect- and worm-repellent activity and is used to render fishing nets more resistant to decay. Traditional medicinal practice uses the sap of young *Avicennia* shoots to cure gangrene, tincture of *Lumnitzera* leaves for mouth infections and an infusion from the wood of *Rhizophora* for diarrhoea (Kokwaro, 1980 and 1985).

Non-wood resources

The enormous amount of litter entering the detrital food web supports high biomasses of commercially valuable species. Fishing provides a protein source for the local community (KBP, 1991) while shrimps (*Penaeus*), crabs (*Scylla* and *Sesarma*) and oysters (*Crassostrea*) are collected and sold to hotels and restaurants. However, the decline in specimen size and total weight of catches (UNEP, 1985a) indicates over-exploitation. Commercial shrimp production has been related to the area of mangrove forest, thus a reduction of mangrove swamps has been related to a remarkable decrease in shrimp yield (Martosubroto and Naamin, 1977; Linden and Jernelov, 1980).

Threats

Mangroves in Kenya are managed by the Forest Department as forest reserves, however, no management practice or silviculture programme is carried out (Van Speybroeck, 1990). The existing mangrove resource is facing pressure not only from unregulated felling, but also from upstream effects of mismanaged watersheds, variation in water quality and quantity caused by inland water works (Tana and Athi River drainage systems) and pollution. Significant felling of trees, with or without licences, has resulted in depletion of the mangrove forest in easily accessible areas such as Kwale, Mombasa and Kilifi Districts, and under-utilisation of less accessible areas. Excessive river sedimentation, due to deforestation and poor agricultural practices, may drown mangrove roots and impede drainage and tidal flows with adverse consequences on the mangrove-dependent fisheries.

North of Ngomeni (north coast) vast areas of mangrove swamps have been converted into ponds for shrimp farming and solar salt production (Rasowo, 1990). Mangroves have been cleared near villages for agricultural purposes, but the development of acid soil conditions, typical of reclaimed mangrove areas, often leads to reduced productivity. The digging of canals in reclaimed mangrove areas causes a change in the freshwater regimes of the adjacent zones, while acid sulphate and fertilizer runoff pollute the creek community. The extensive grasslands of seasonal back swamps are used for cattle and goat grazing. Epiphytes, such as orchids and ferns associated with palm trees and shrubs in these back swamps, are being depleted for use as ornamental plants for tourist resorts.

In urban and industrial areas mangroves are used as dumping sites of domestic and industrial solid wastes. The municipal, domestic and industrial wastes of Mombasa are dumped near Makupa and Tudor Creeks and toxic chemicals seep into the creeks. There is also considerable pollution of the creeks around Mombasa due to domestic sewage disposal and storm water runoff (Munga and Delbeke, 1991). An oil spill in Makupa Creek behind the port area killed all mangroves and associated mangal (KBP, 1990).

Seagrasses

Description and occurrence

Seagrasses (marine angiosperms of the families Hydrocharitaceae, Cymodoceaceae and Zosteraceae) are unique in the marine environment as they are the only flowering plants growing underwater on shallow soft bottom sediments. They occur in the intertidal zone to depths well beyond the reefs and may form extensive meadows.

The importance of seagrass ecosystems has only recently been recognized, thus information on this zone in Kenya is very scarce (Isaac, 1968; Njuguna, 1985; De Wit, 1988; Coppejans, 1990; Maudsley, 1990). Seagrass beds occur in patches along the coastline and sometimes extend into the creeks. There are 12 species on the Kenyan coast (*Cymodocea rotundata, C. serrulata, Enhalus acoroides, Halodule uninervis, H. wrightii, Halophila minor, H. ovalis, H. stipulacea, Syringodium isoetifolium, Thalassia hemprichii, Thalassodendron ciliatum* and *Zostera capensis).* The most common and widespread species are *Thalassia hemprichii* and *Thalassodendron ciliatum*, while *Enhalus acoroides* forms dispersed local patches. *Halodule* is the main pioneer genus, colonizing new areas of the seabed or recolonizing damaged areas. Seagrass distribution and zonation is linked to substrate type, salinity and duration of emersion at low tide. A zonation scheme has been described for the Gazi area only, but can be generalized for the entire Kenyan coast (De Wit, 1988; Coppejans, 1990; De Pauw, 1990).

Although inconspicuous compared with other coastal systems, seagrass meadows make an important contribution to the production of coastal waters. They are highly productive, rich in fauna and ecologically important habitats. They provide nutrition, habitats and protection for large populations of invertebrates and fishes (Zieman, 1982). Many marine species within the mangroves and the coral reefs use seagrass beds as their nursery, breeding and feeding grounds.

There is little quantitative information on the productivity of seagrasses. A dense seagrass meadow may consist of more than 4,000 plants/m^2, with a standing crop biomass (above sediment) of 1-2 kg/m^2 dry weight (Njuguna, 1985). The average gross primary productivity for seagrass beds reaches 4,650 g C/m^2/year (Zieman, 1982; UNEP, 1985b; Durako *et al.*, 1987). Seagrasses absorb nutrients from the sediments via their roots and release nutrients through their leaves, thus acting as a nutrient pump from the sediment. This process contributes to the productivity of nearby nutrient-poor waters of coral reefs (Zieman, 1982; Hemminga and Slim, 1990). The rhizome-root system also helps to trap sediments and stabilize the near-shore bottom, providing a suitable habitat for numerous benthic macroalgae, while seagrass leaves are important substrata for epiphytic algae (Coppejans, 1990). These associated algae (*Euchema, Gracilaria, Ulva* and *Sargassum*) make an important contribution to the overall primary productivity of the seagrass beds and also have an economic value.

There are two major pathways along which the seagrasses play a vital role in the food web: direct herbivory and detrital contribution (Zieman, 1982; Durako *et al.*, 1987). Primary herbivores graze seagrass meadows; these include sea turtles (*Chelonia, Eretmochelys*), dugongs (*Dugong dugon*), sea urchins (*Echinometra, Diadema*), molluscs (*Strombus*) and several fish species (Siganidae, rabbit fishes; Acanthuridae, surgeon fishes; Ostraciontidae, boxfishes). Parrotfish (*Leptoscarus*) and crustaceans, such as hermit crabs (*Pagurus*), preferentially graze the epiphytes on the seagrass. Today both turtles and dugongs are scarce and the largest part of the standing crop of seagrasses remains unconsumed. The detritus food web has been considered the main pathway of trophic energy transfer from seagrasses to the animal community (Durako *et al.*, 1987). Up to 80% of the net production in seagrass beds becomes detritus, either by dying and being metabolised *in situ* or by being exported to adjacent ecosystems such as mangrove creeks and coral reefs.

Many crustaceans, such as amphipods, isopods and crabs, feed on epiphytic algae as well as detritus. Shrimps, many fish species and larger gastropods are omnivorous while sea cucumbers (Holothuridae) and some fish (mullets, gobies and blennies) are typical detrital feeders. Adult fishes, such as snappers, groupers, grunts and barracuda, feed on the infauna of seagrass beds while the diet of their juvenile stages is mainly detritus.

The biota present in seagrass beds can be classified in a scheme that recognizes the central role of the seagrass canopy:

1. Epiphytic: macroalgae, barnacles, sponges, meiofauna (Van Avermaet, 1990).
2. Epibenthic: gastropods, sea urchins, sea cucumbers, sponges, macro-algae, crustaceans.
3. Infaunal: polychaetes, nematodes.
4. Nektonic: crustaceans, fishes, turtles. Many are seasonal residents or temporal migrants (diurnal or nocturnal feeders) (Zieman, 1982).

At low tides seagrass beds are also used as feeding grounds by diving and wading birds such as cormorants, herons, egrets and ibises.

Values and utilisation

Ecological

Seagrass beds provide shelter and food for many ecologically important species. They act as sediment traps, improving the water clarity and contributing to the protection of the shoreline by reducing wave actions. They are highly efficient at removing nutrients from seawater and sediments, and export organic material and nutrients to neighboring systems.

Economical

As mentioned above seagrass meadows are important breeding, nursery and feeding grounds for several finfish and shellfish of commercial value such as siganids, lethrinids, lutjanids, scarids, shrimps (*Penaeus*) and spiny lobster (*Panulirus*). Leaves of seagrasses, particularly *Enhalus acoroides*, are used for weaving mats and the rhizomes of *Enhalus* are used as food in the Lamu area ('mtimbi'). The associated brown algae (*Turbinaria, Sargassum*), green algae (*Ulva*) and red algae (*Hypnea*) are used as bait in fish traps. The most important economic value of the inshore seagrass beds is their associated artisanal fishery. Fishing is mainly carried out with fish traps, beach seining and trawling. Commercial shrimp trawling is found mainly in Ungwana Bay. Sea cucumber (*beche-de-mer*) is collected at low tide for export. Potential uses include the culture of red algae (*Eucheuma* and *Gracilaria*) for carrageen and agar products (Wamukoya, 1990). Dead seagrass or seaweed, lying in huge amounts on the beaches, can be collected for mulching, composting or green manuring.

Threats

There are no existing management practices for seagrass beds *per se* (UNEP, 1985a). Seagrass areas located within national parks and reserves are protected from physical destruction but not from pollution and sedimentation whose origins are beyond the control of park officials. Sedimentation due to riverine deforestation and agricultural activities (Sabaki and Tana Rivers) forms a serious threat. The turbidity induced by suspended sediment and sediment settling on the plants impairs photosynthesis and growth of seagrasses and associated algae. Most sewage outlets empty some distance from the beach in the lagoons or in the nearby creeks. The resulting eutrophication induces phytoplankton blooms which in turn lower light penetration.

Direct destruction occurs mainly by trawling activities and by boat propellers in areas with tourist resorts. The most important threat to the seagrass community is over-fishing of the inshore waters. Higher fishing pressure, associated with reduced yield and smaller fish sizes, indicates that this resource is being over-fished in many locations (Samoilys, 1988).

The commercial shrimp trawlers in Ungwana Bay are not only destructive and non-selective, but have also a fishing effort well beyond the potential sustainable yield in that area (Sanders *et al.*, 1990). Illegal trawling activities within the ten mile zone put heavy pressure on juvenile fish stocks and sea turtles.

Coral reefs

Description and occurrence

The coral reefs of Kenya are mostly fringing reefs running roughly parallel to the coast at distances of 0.5-2.0 km from the shoreline. Gaps occur near the mouths of (seasonal) rivers due to the silt load, low salinity of the water and the lack of hard substrata. In certain areas there are offshore patch reefs and islands, such as Kisiti, parts of the Malindi reef and the Lamu archipelago.

About 140 different species of hard and soft corals have been identified along the Kenyan coast. The best known reefs are in the Malindi-Watamu area (Hamilton, 1975; Hamilton and Brakel, 1984). Fauna and flora associated with the reefs have been described (Jones, 1969; Khamala, 1971; Bock, 1975 and 1978; Hamilton, 1975; Muthiga and McClanahan, 1987; McClanahan and Muthiga, 1988 and 1989; Samoilys, 1988; McClanahan, 1989 and 1990; Gray, 1991; KBP, 1986-1991).

A coral reef is one of the finest examples of a biologically productive and taxonomically diverse ecosystem. The high productivity arises from extremely efficient biological recycling and retention of nutrients while the complex structure provides habitats for a vast array of other organisms (Bock, 1978; Veron, 1986; Wells, 1988). The polyps of the hermatipic corals (colonial forms) collectively deposit calcium carbonate as a protective cup around their soft bodies. Their colonies increase by budding while they disperse through a sexual process which releases planktonic larvae. Symbiotic algae (zooxanthellae) live within the polyp tissues, processing the polyp's waste products, hence retaining vital nutrients in this nutrient-poor environment and giving corals their spectacular colours. In their turn the polyps receive oxygen and 94-98% of their total food requirements, the rest being filtered from the water column during the night (Bock, 1978; Veron, 1986). Corals are slow-growing organisms and need clear, well-oxygenated water. Massive round forms (*Millepora*) grow up to 2 cm/year, while branching forms (*Acropora*) may grow between 3 and 10 cm/year. It can be estimated that the building of a reef represents 5,000-10,000 years of coral work.

This efficient and rapid recycling of nutrients forms the backbone of the reef ecosystem. Its average gross primary productivity reaches 4,200 g C/m^2/year (UNEP, 1985b). The physical complexity of a reef contributes to its diversity and productivity. Food webs on the reef are exceedingly complex with an intricate balance of many predator-prey relationships and dependencies. But this delicate balance can easily and rapidly be upset by any intrusion. The productive processes of coral reefs and the life cycles of their inhabitants are closely linked to the neighboring seagrass beds and mangroves.

Values and utilisation

Ecological

Coral reefs have been identified as one of the essential life-supporting systems necessary for human sustainable development in tropical coastal areas (Wells, 1988). In addition they protect the coastline against wave and storm action, prevent erosion and contribute to the formation of sandy beaches.

Economic

The accessibility of Kenya's reefs, being close to the shoreline, makes them very valuable for tourism and fisheries but also extremely vulnerable to terrestrial and human influences.

Coral reefs are a source of building materials, jewellery, ornamental objects and medical products (antibiotics, drugs). Above all they provide an important food source. At least 50% of the fish catch at the Kenyan coast is reef-associated fish, caught mainly by artisanal fishermen whose livelihoods depend on the status of the reef fishery (Dubois *et al.*, 1985; Samoilys, 1988).

The most important revenue from Kenya's coral reefs is the tourist industry (UNEP, 1984b). Tourism is now Kenya's largest foreign exchange earner and the industry has become one of the country's largest employers (Schoorl and Visser, 1991). With its marine resources the coast attracts many more tourists than any other area and environmental problems which could affect the tourist industry cause great concern. The attraction of tourists to the coast depends on maintaining clear blue waters, white sandy beaches, biologically rich reefs for snorkeling, diving and sportfishing, accessibility of the reefs and abundant seafood.

Threats

The marine parks and reserves are administered by the Kenya Wildlife Service. In the parks, fishing, collecting or disturbance of marine organisms is totally prohibited. In the reserves only traditional fishing is allowed (handlines, traps, beach seines in shallow waters and gill-nets in deeper waters). However, legislation is not adequately enforced (Ray, 1969; Dubois *et al.*, 1985; Samoilys, 1988).

A number of complex interrelated factors may impact on coral reefs and their multiplied effect reduces the characteristic rich diversity of the reef to a monotonous community which has lost its complex structure and high productivity.

Directly-related impacts

Boating causes anchor damage, grounding destruction; outboard motors cause damage and disturbance, as does jetskiing in shallow waters. Snorkeling and diving disturbs reef organisms when coral is stood on and broken; in some areas there are increasing numbers of divers. Tourists damage the reef by walking on the reef crest and shallow reef patches, and by turning over of coral boulders and rocks without replacing them.

The collection of shells and coral (Samoilys, 1981; Kendall, 1984), starfishes, sea turtles (UNEP, 1985a) and fishes such as porcupine, puffer and box fishes takes place for the souvenir trade. Careless collecting methods with hammer and crowbars have led to habitat damage. Several types of molluscs are already endangered i.e. helmets, tritons and cowries (Kendall, 1984; UNEP 1984a, 1989; Wells, 1988). Legislation was enacted in 1971 when a quota system was introduced but bag limits have rarely been enforced. Speargun fishing leads to selective depopulation of large fish species such as groupers, parrotfish and surgeonfish. In spite of being illegal in Kenya its practice is still continuing.

Indirectly-related impacts

Fishing pressure, caused by large numbers of tourists and the increasing coastal population, has already caused over-exploitation of lobsters, crabs, prawns and some fish by intensified and unsustainable fishing practices at Diani, Mombasa and Shimoni (Ray, 1969; Wells, 1988). Dynamite fishing in Shimoni has very destructive effects to the whole reef community (Samoilys, 1988). Trawling and beach seines damage coral outcrops while small mesh size captures juvenile fish. In the long term this affects the reef's diversity and productivity. Collection of ornamental aquarium fishes, especially angelfish and cleaner wrasses, is not controlled and often uses harmful and damaging methods.

Over-exploitation of parts of reefs in Malindi, Diani and Mombasa causes loss of diversity (Dubois *et al.*, 1985; McClanahan, 1987; McClanahan and Muthiga, 1988; Samoilys, 1988).

Near-shore discharge of sewage effluents causes eutrophication with consequent increased blooms of phytoplankton, decreasing light penetration in surface waters and increased growth of benthic algae relative to corals. Tropical waters are naturally nutrient-poor and such enrichment damages the ecological balance so that coral reefs turn into algal reefs, as seen in parts of the Mombasa and Diani reefs (Samoilys, 1988). The effluents also have public health risks which may have effects on the sustainability of tourism.

Silt, together with agrochemicals, is carried in river runoff to inshore environments (Blom, 1985). The sediments smother corals, obscure the light needed by their zooxanthellae and hinder the settling of coral larvae. Thus large areas of the northern Malindi reef have areas of dead coral or monotonous *Acropora* stands. Beaches have expanded but with dirty muddy sediments (Waning and Hafkenscheid, 1983; Giesen and Van der Kerkhof, 1984; Dubois *et al.*, 1985; Samoilys, 1988). Dredging practices have similar adverse effects on the Mombasa and Shelly Beach reefs.

Interactions between mangroves, seagrasses and coral reefs

Although there is a great amount of literature on these three coastal systems, little is available on the interactions between them (UNEP, 1985b). Nutrient transfer from seagrass beds and mangroves to coral reefs occurs as a result of tidal effects and fishes or invertebrates foraging on the seagrasses and subsequent excretion on the reef. This leads to higher growth rates of corals and larger biomass of fish in the immediate vicinity of seagrass beds (Zieman, 1982). Also recruitment to the coral reef fish community occurs due to nearby nursery grounds in the seagrass meadows and mangrove creeks (Van der Velde, 1990). During their life cycle many fish and crustaceans depend on the three biotopes; they spawn offshore, spend their juvenile stages in seagrass beds and/or mangroves and return to the reef as adults (Durako *et al.*, 1987). All three systems influence each other favorably by stabilizing the physical environment, dissipating wave actions (mostly by coral reefs), buffering salinity gradients (mostly mangroves) and stabilizing sediments (mangroves and seagrasses). Coral reefs are the most susceptible to damaging effects of siltation and terrestrial runoff of nutrients, while mangroves are the most tolerant and generally benefit from nutrient rich runoff. Disruption of these biological or physical interactions leads to lower productivity and simpler ecosystem structures.

Recommendations

Many recommendations have already been listed, the main constraints being expertise and finances. Management policies should have an integrated approach and incorporate research programmes. Conservation of coastal wetlands and coastal development requires a greater knowledge of the ecosystems, their ecological interactions and their interfaces with the land. There is also an urgent need to improve management of existing protected areas.

Sustainable multi-use development planning must have an ecological base if one wishes to maintain the productivity and integrity of these marine ecosystems. This requires multi-disciplinary and inter-institutional cooperation. A national coordination unit should be set up together with a database of all existing studies and programmes.

There is an urgent need to initiate directed research and activities in such areas as topography and regeneration of mangroves, silviculture and mariculture programmes. There should be inventories and studies of wetland communities, fish stocks and sustainable fishing pressure, pollution monitoring and surveys of human impact on the biotopes (Jaccarini and Martens, 1990). There is a need for enforcement and improvement of existing regulations, but laws will only be effective when resources to enforce them are present (trained staff and equipment) and where local people are able to obtain sufficient income for their daily needs. Immediate integrated management practices would be feasible if mangroves adjacent to marine parks were under the jurisdiction of the Kenya Wildlife Service. Felling of mangroves should be strictly controlled and only allowed in exploitable zones such as in Lamu District.

The introduction of zonation schemes related to specific uses in mangrove forests and marine parks would help to control harmful activities. The gazetting of proposed parks and reserves (Figure 1) would provide more undisturbed replenishment areas and refuges for breeding stocks, as well as sanctuaries for such endangered species as the sea turtle. Permanent moorings, like those in Malindi, Watamu and Shimoni, would prevent anchoring on the reef. The ban on collection and trade of shells and marine organisms in Kilifi District can only be really effective if this regulation is followed nationwide.

Fishing grounds should be relocated to the under-utilised deeper waters behind the reef but this would not be suitable for artisanal fishing methods. In the long term, yields may improve if fishing pressure could be spread evenly along the coast, together with limitations on mesh size. A clear demarcation of the marine parks, as in Shimoni, will provide appropriate guidance to the local fishermen.

Measures to stop further depletion of crustacean stocks are the introduction of size limits and fishing seasons. There is an urgent need for the establishment of adequate treatment and disposal systems for sewage and waste products. Hence the adoption of effluent guidelines and water quality standards may be valuable tools.

The social and economic situation of the local people is also an important factor to be considered as poverty and ignorance are underlying causes of environmental degradation. Public awareness campaigns for the local population on the values of the coastal wetlands, the purpose of conservation activities and the importance of parks and reserves should be launched. The success of introducing new approaches for sustainable management of natural resources largely depends on the understanding and acceptance of these regulations by the public and by local communities.

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Wetlands and tourism

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A tourist is someone who travels for pleasure; tourism dates back to the days of the ancient Greeks and Romans who set out to see remote corners of their empires and remained a hobby for the elite until after the second World War. In the 1950s and 1960s tourism was epitomized by the tourist travelling from one site of interest to another.

Mass tourism is mostly characterized by the fact that the mass tourist will stay in one place. This is partly caused by modern transportation, aeroplanes and long-distance buses, which leave people without individual means of transport. Thus, a day excursion is as far as a mass tourist will go.

In Kenya there is mass tourism at the coast and elite or more-or-less individual, safari tourism up-country. A third category of tourists in Kenya are the local tourists who do not like to mix with the mass tourists on the one hand and cannot afford to follow the pattern of the elite tourist on the other. They take advantage of the lower prices of lodges and hotels in the off-season from February to June. These tourists are usually very well informed; they know exactly where they are going and what they want to see or do. This group is growing with increasing individual mobility and the increase of a middle class in Kenya. Their limited budget calls for the development of a moderately priced category of hotel accommodation.

Over the past few years around 800,000 tourists visited Kenya annually. Roughly, they can be divided into 50% mass tourists, with the coast as their destination, and 50% as elite or quasi-individual safari tourists who will visit the up-country parks.

The coastal tourist is mainly interested in the sun and the beach and probably some other aspects that fall outside the scope of this workshop. He does not know what to expect from Kenya other than nice weather and a package holiday in an exotic-sounding country. His budget is limited; the charter plane will pick him up exactly 14 days after it dropped him, meanwhile the hotel will virtually lock him up to squeeze some profit out of his holiday drinking habits. Because of the over-capacity of hotel beds on the coast there is hardly any profit to be made out of the accommodation and meals.

The impact of this type of tourism on coastal wetlands is basically negative. Hotels are being constructed in an uncontrolled way occupying the most scenic spots on the coastal strip, disturbing sea currents and causing coastal erosion by the erection of structures on the beach. For the construction of spectacular Swahili roofs, large quantities of mangrove poles are used contributing to the degeneration of that wetland ecosystem. Drinking water is transported by pipeline from hundreds of kilometres away, for instance from Mzima Springs, to allow tourists to use five times more water per day than a coastal Kenyan. Removing this freshwater has far reaching consequences for wetlands up-country as well as on the coast.

Animal and plant life in the coastal lagoons and on the tidal reefs is being polluted by hotel and swimming pool effluent, and disturbed and trampled by generations of innocent tourists exploring a new world. Thus sea-turtles rarely nest on the Kenyan coast today and tourists eat the last of the Kenyan lobsters and prawns. At least those who visit the national parks and reserves pay some money in exchange for the damage their flippers do to the corals.

In April 1991, the Netherlands Embassy organized a workshop on sustainable coastal tourism which addressed the issues above. The following recommendations for action were made:

1. controlled coastal and hotel development, both in terms of physical planning and in environmental management;
2. better information to the tourists about the coastal environment;
3. increasing the size and number of protected coastal areas.

But recommendations alone will not solve the problems and therefore the Netherlands Government is seriously considering assisting the Kenya Wildlife Service (KWS) in upgrading the management of the protected coastal wetlands. This assistance is planned to go beyond the present activities of KWS. It is extremely important that the voice of nature conservation be heard in the planning and environmental management of new and existing coastal developments and in the management of coastal natural resources.

Now let us move inland and look at the other 50% of international tourists. These tourists come for a differently-orientated holiday than their coastal counterparts. In general they are better prepared in terms of their expectations; some will have a special interest in nature or a specific interest, say, in birds.

Bird watchers are a growing group. Figures from Western Europe show a steady increase in the membership of bird conservation organisations. In the Netherlands membership of Vogelbescherming grew from 10,000 in 1960 to 65,000 in 1990. In the United Kingdom members of the Royal Society of Bird Preservation grew from 10,000-636,000 over the same period. With its comparatively large numbers of different bird species, Kenya forms an attractive destination for this growing group of ecotourists.

The 400,000 inland safari tourists follow certain migratory patterns, rarely skipping either Masai Mara or Amboseli. The eastern routes tend to include Amboseli and Tsavo, while the western routes include Nakuru, Naivasha and Masai Mara. Most of the circuits include one or more wetlands.

In one particular wetland, Lake Baringo, the Lake Baringo Club's resident ornithologist more than covers her salary through birdwalks and boat trips. The majority of safari tourists are confronted with Lake Baringo's bird life on a semi-compulsory basis as the birdwalk is included in the trip. Some of them even like it! The tourist to Lake Baringo has the chance to spot over 170 different wetland related birds and more than double that number in the cliffs surrounding the lake.

A Netherlands Government financed activity has had an impact on the future of tourism in the Baringo area. Over the past 50 years Lake Baringo has lost 50% of its water volume due to siltation and evaporation. It has been calculated from aerial pictures and satellite images that by correctly managing 1,000 km^2 in the Baringo Basin, the erosion into the lake can be virtually stopped.

The Baringo Fuel and Fodder project, financed by the Netherlands Government, is reducing the erosive processes and turning the degraded land into productive ecosystems once more. The applied techniques are quite rigorous; heavy machinery makes contour dykes that will stop the erosive sheet flow. Trees are planted along the dyke and grass regenerates. However, the trick is to regulate the use of the regenerated land on a sustainable basis. Therefore public participation in understanding the limits of the land's carrying capacity and complying with this is essential. Hopefully measures taken by this project will be expanded to save Lake Baringo from certain siltation 20 years from now.

Figures for Lake Nakuru National Park show that KSh 20 million was earned from 151,794 tourists in 1990. Thus significant profit can be earned from wetlands which tourists find interesting.

Despite all these tourists bringing in money for inland wetland conservation and management, there are negative impacts of tourism on wetlands. Increasing numbers of vehicles visit Nakuru; these vehicles need good roads and are themselves a cause of air pollution and disturbance. Despite this, inland wetland tourism is beneficial although there is plenty of room for improvement.

The management of protected wetland areas has never been identified by Kenya Wildlife Service (KWS) as a separate form of management. The Netherlands Government and KWS are considering setting up and funding a wetlands programme within the KWS planning division. This programme would not only coordinate all wetlands related issues in the KWS context but it would also provide the basis for KWS' responsibilities deriving from the Ramsar Convention membership. KWS, as the executive agency within Kenya for conservation, is responsible for the wise utilisation of all wetlands in Kenya. Of course KWS cannot perform this task in isolation, it will have to initiate the setting up of a strong inter-ministerial body that will have the difficult task of formulating and executing a country-wide, or wetland-wide, policy.

In conclusion, five wetland oriented actions are recommended to develop and safeguard the financial resources derived from tourism. These are to:

1. **improve the quality of the sewage water discharged into Lake Nakuru;**
2. **stop the inflow of agrochemicals into Lake Naivasha and let an Environmental Impact Assessment form the basis of the decision whether or not to remove water from Lake Naivasha to supply drinking water to Nakuru town;**
3. **accelerate anti-erosion activities around Lake Baringo;**
4. **include mangroves, that now fall under Forestry Department, in the KWS management of marine protected areas;**
5. **make the Tana River Delta a protected area, including a large area of freshwater wetland north of the river and develop tourism infrastructure.**

Tana River Delta wetlands

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Summary

The Tana River Delta is the largest delta ecosystem in Kenya and functions as a single ecological system whose various components are interconnected. The most important factor impacting upon the human and natural components of the system is water. The delta maintains high levels of productivity in a dynamic balance which revolves around and is strongly influenced by timing, extent and duration of flooding. Vertical and horizontal water circulation transports nutrients, influences a wide variety of habitat types, flushes away wastes, controls salinity, and disperses and nurtures larval stages of aquatic organisms.

Traditional land-use practices of small-scale agriculture, pastoralism and fishing have maintained the ecological balance of the Tana Delta for thousands of years. It is essential to integrate environmental considerations into the management and development of the delta area with the objective of reconciling interests and ensuring that the development of the natural resources is in harmony with the ecological processes. The output of such an activity will be a harmonized wetland environment which is sustainable from social, cultural, economic and ecological view-points.

The management and conservation of the Tana River Delta wetlands ecosystem can only be successful if built upon a strong database. Elaborating and understanding the structure of the delta's links with the wider natural environment is a high priority. The struggle to produce more food, reduce disease and raise living standards can be accomplished in the Tana River Delta on a sustainable basis without disrupting the ecological balance of the wetlands.

Introduction

The Tana River is the longest river in Kenya with a total length of approximately 1,000 km and a catchment area of 95,000 km^2 (Marsh, 1976). It originates from the eastern slopes of the Nyandarua Range (Aberdares) and the southern slopes of Mount Kenya. The river flows for most of its course across semi-arid and arid regions and meanders through an alluvial floodplain varying in width from 2 km in the middle reaches to 42 km in the lower reaches. The Tana River enters the Indian Ocean through the main channel and a series of distributaries which form an extensive deltaic wetland downstream of Garsen (Figure 1). Seasonal floods cause the formation of new river channels leaving behind cut-off levees, meanders, oxbow lakes and other open water bodies which characterize the extensive and ever-changing micro-topography of the Tana floodplain wetlands.

The entire floodplain in the lower reaches is covered by recent alluvial sediments, transported and deposited during the annual flooding of the river. The delta has diverse habitats and high productivity resulting from a dynamic equilibrium of water, soil, topography and coastal influences. Thus formed is a fragile, vast and unique ecosystem which is the habitat for abundant flora and fauna. The delta maintains vast numbers of wild herbivores: nearly 10,000 topi, thousands of waterbuck and hippotamus, and around 100 elephants as well as the largest concentration of crocodiles in Kenya.

A huge irrigation project has been initiated in the Tana River Delta (Nippon Koei, 1988). This project is expected to cover 16,000 ha of land normally used by the pastoralists as a dry season grazing area. The Garsen-Lamu road has recently been constructed across the floodplain and formed an embankment which has impended natural drainage and caused permanent flooding upstream with deleterious consequences.

Traditional land-use in the delta has in the past been integrated with the balanced functions of the ecosystem; this must be maintained as a basis for sustainable use of the natural resources not only by people resident within the delta but also in the surrounding areas. Any development activity which is implemented without due consideration to the fragility of the delta ecosystem, and the local communities that depend on it, may destroy the delicate balance which sustains the high productivity. Any development schemes for the delta must be analyzed with respect to their impact on the natural environment, the traditional communities and their patterns of life.

Tana River Delta habitats

The Tana River Delta ecosystem is unique and encompasses a large number of habitats - including riverine forests, grasslands, woodlands, bushlands, lakes, mangroves, sand dunes and coastal waters - and an enormous biological diversity.

Riverine forests

Five subtypes of riverine forests in the upper part of the delta are distinguished and include mixed evergreen forests, mixed forest variant, *Acacia/Diospyros* forest, *Garcinia* forest and cultivation forest type.

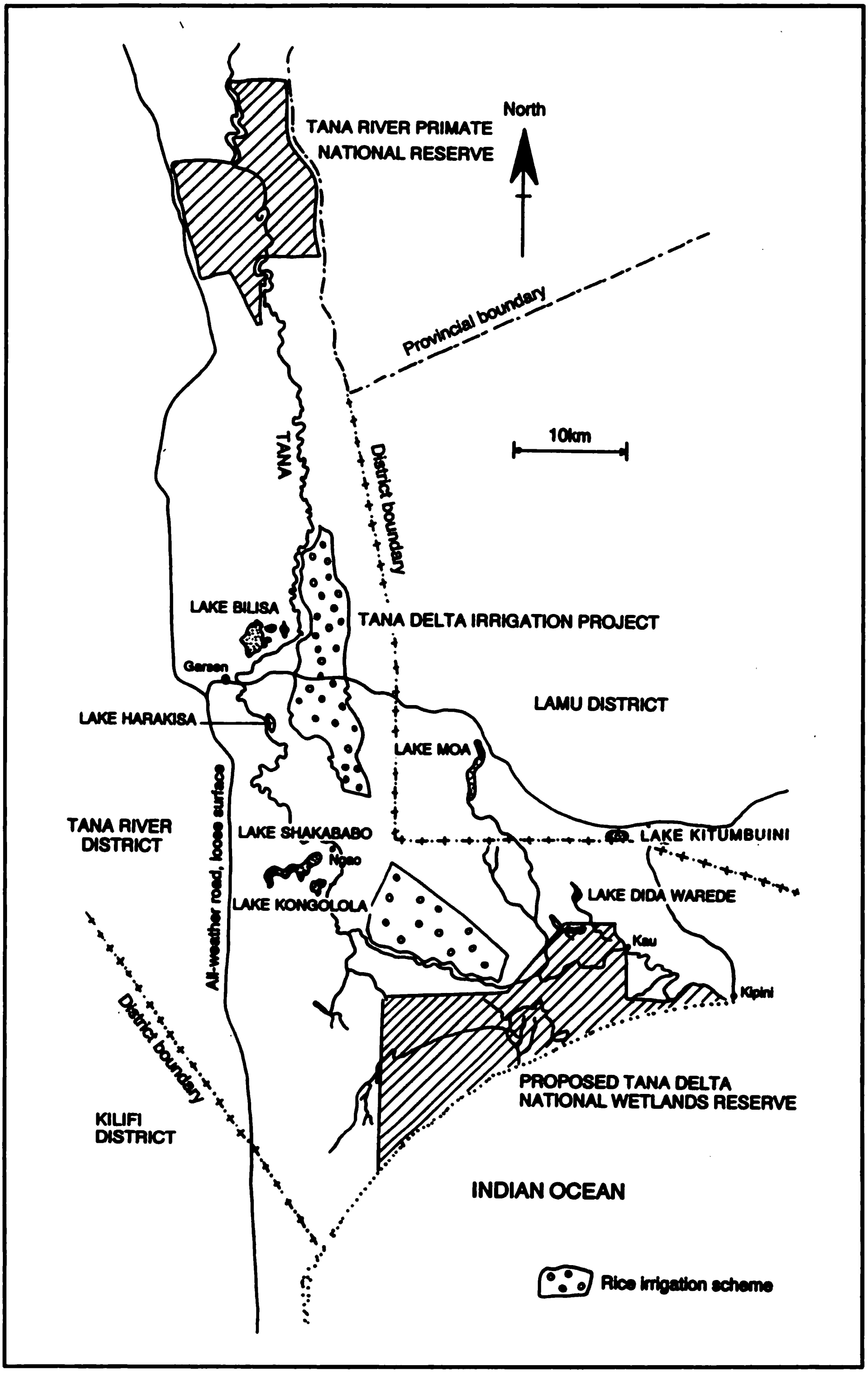

Figure 1 Tana River Delta wetlands and proposed developments

Mixed evergreen forests have a main canopy height of 15-25 m with emergents reaching 35 m. They are best developed on high sandy levees and are dominated by *Ficus sycomorus, Diospyros mespiliformis, Sorindeia madagascarensis* and *Pachystela msolo.* These tree species are important food resources for two endangered and endemic subspecies of primates, the Tana River Red Colobus (*Colobus badius rufomitratus)* and the Tana River Mangabey (*Cercocebus galeritus galeritus)*. The population dynamics and behaviour of these primates have been documented by Homewood (1976), Marsh (1978), Decker (1989), Kinnaird (1990), Medley (1990) and Ochiago (1990).

The mixed forest variant is dominated by *Pachystela mosolo* with *Majidea zanguebarica* and *Alangium salviifolium* often common in the understory to 10 m. This forest type is found exclusively on high sandy levees, near the river, which receive low frequency flooding.

Acacia/Diospyros forest is characterized by *Acacia robusta* and *Mimusops fruticosa*; in certain areas co-dominance is shared with *Acacia elatior*. This forest type has a rather high open canopy (25-30 m) and is found 500-1,000 m away from the river on soils intermediate between the sand of the river bank and the fine clays of the backwater areas.

The *Garcinia* forest type forms a closed canopy at 13-16 m and is found on clay soils which are subject to regular, light flooding. It is characterized by an abundance of *Garcinia livingstonei, Cynometra suahliensis* and *Cola clavata*.

Cultivation forest type is a late secondary succession association immediately identifiable by the presence of mango trees (*Mangifera indica)* or aggregations of *Borassus aethiopum. Ficus sycomorus* and *Afzelia quanzensis* are common forest colonizer species.

These forest types supply the local communities with fuel wood, material for canoe construction, medicinal products, bee hives, drum frames, tool handles, mats, baskets, twines, construction palm fronds and also support the endangered primate populations and other fauna.

Grasslands

The greater portion of the Tana Delta, approximately 67,000 ha, is covered by floodplain grasslands. Seasonal flooding and poorly drained soils are important factors in maintaining these natural grasslands. A variety of grassland associations occur, including a widespread tall grass type found in heavy black clays and areas with open water which is dominated by *Echinochloa haploclada* with *Bothriochloa glabra, Setaria splendida* and other less common species. Sedges (*Cyperus* spp.) are common in the wetter areas and they may be dominant in permanent swamps. In areas with more sandy soils and less risk of flooding, usually the levees associated with the old and present Tana River courses, a variety of grass species occurs. The two main grasses are *Digitaria alscendens* and *Sporobolus confunis*. A third grassland type is dominated by tall stands of *Panicum maximum* growing to a height of over 2 m in places. On the inland side of the coastal sand dunes and mangroves, a salt tolerant grassland occurs which is dominated by the tough, spiky *Sporobolus spicatus* in association with the salt bush *Suaeda monoica*.

The Tana Delta grasslands are important dry season and drought fallback grazing areas for Orma pastoralists. The grasslands also contribute to the replenishment of nutrients essential to sustaining the fishery industry during the flooding and drawdown cycles.

Woodlands and bushlands

Two types of woodlands, wooded grassland and wooded bushland, occur in the Tana River Delta. The wooded grassland is found to the east of the floodplain and merges with the Boni forest type to the north. The principal trees are *Diospyros cornii, Lannea stuhlmanii, Dobera glabra* and *Terminalia spinosa*. Dominant grass species are *Panicum maximum* and *Digitaria mombasana*. Fire-resistant doum palms *(Hyphaene coriacea)* are common and swampy areas are ringed by the Borassus palm (*Borassus aethiopum)*.

Wooded bushland is confined to the sand dunes and coastal ridges where limited flooding may occur during exceptional floods. It is dominated by *Dobera glabra, Commiphora schimperi* and *Grewia* spp. and is associated with the *Acacia-Euphorbia* dry thorn bushland (Nyika) bordering it to the west (Ecosystems, 1985).

The bushland associations include bushed grasslands, grassed bushlands, palm-bushed grasslands and riverine bushlands. These form a complex mosaic with the floodplain grasslands. The definition of bushed grasslands and grassed bushland is based on the woody canopy cover. The former is defined as having less than 20% and the latter has 20% or more woody canopy cover respectively (Ecosystems, 1985). Tree species include *Acacia robusta, Acacia zanzibarica, Terminalia spinosa* and *Tamarindus indica*. Shrubs are dominated by *Thespesia dania, Carissa edulis, Terminalia* sp. and *Rhus natalensis*. In certain areas, especially to the south of Lango la Simba, a palm-bushed grassland occurs with dominance of one of the palms *Borassus aethiopum, Hyphaene coriacea* or *Phoenix reclinata*.

Lakes

In the basins of oxbow lakes and the deeper parts of the drawdown lakes where water remains for most of the year, profuse growths of true aquatic plants occur. The Nile cabbage or water lettuce *(Pistia stratiotes)* carpets the water surface and interspersed with it are the water lily (*Nymphaea lotus*) and the floating aquatic fern (*Azolla nilotica*).

Several lakes and permanent marshes occur in the Tana River Delta covering an estimated area of 10,000 ha. These include Lakes Bilisa, Shakababo, Kongolola, Kitumbuini, Dida Warede, Harakisa, Moa and Kenyatta.

Lake Bilisa, located just north of Garsen, is an expansive wetland dominated by grasses, sedges, floating macrophytes and submerged macrophytes. The dominant plant species include aquatic grasses (*Bothriochloa bladhii, Echinochloa haploclada*), sedges (*Cyperus frerei, C. heterophylla, C. tuberosus*), floating macrophytes

(*Pistia stratiotes, Azolla nilotica, Lemna* spp.) and submerged macrophytes (*Ceratophyllum demersum*). The lake has abundant bird life. Fishing is a major activity; in 1990 the yearly fish landing was 145,000 kg with a value of KSh 3.2 million. The Orma people harvest the aquatic grasses as fodder for milk cows and calves and use sedges for thatching. The lake has a high potential for tourism.

Lakes Shakababo and Kongolola are divided by the bridge between Tarasaa and Ngao settlements. The water in the two lakes is relatively clear. Various species of fish are caught including 'Barabara' (*Oreochromis mossambicus*), 'Chokole' (*Synodontis zambesiensis*), 'Pawa' (*Mormyrus* sp.), 'Pumi' (*Clarias mossambicus*), 'Borode' (*Labeo gregorii*), 'Kamongo' (*Protopterus amphibius*) and 'Mkunga' (*Anguilla mossambicus*). Fish landings in 1991 from the two lakes weighed 82,000 kg with a value of KSh 1.8 million.

Lakes Harakisa, Kitumbuini, Dida Warende and Moa are utilised by the Orma as dry season grazing areas and by the Luo and Luhya as fishing grounds. The lakes have a wide variety of waterfowl species. At Lakes Harakisa and Dida Warede are heronries which should be conserved as bird sanctuaries.

Lake Kenyatta, near Mpeketoni, is the largest inland water body in the delta. Although the lake does not receive the Tana River water directly, it is important as a waterfowl habitat. The shoreline of the lake is covered with a band of the Nile cabbage (*Pistia stratiotes*). The lake is eutrophic due to nutrients originating from the settlements along the northern shore and the water is coloured green due to a high concentration of the blue-green alga (*Microcystis aeruginosa*).

Mangroves

Three areas of mangroves occur in the lower part of the Tana Delta. The largest of these occurs near the present outlet of the Tana River at Kipini. This area has the tallest mangroves in the coastal area. The other two areas are situated near the old mouths of the Tana River at Mto Kilifi and Mto Tana. Near Shekiko Camp is a network of channels containing salt water and lined by mangrove forest.

The dominant mangrove species is *Avicennia marina; also* present are *Sonneratia alba, Rhizophora mucronata, Ceriops tagal, Lumnitzera racemosa, Xylocarpus granatum, Bruguieria gymnorrhiza* and *Heritiera littoralis*. On the slightly elevated areas within the mangrove forests, small areas of non-mangrove vegetation are found which includeb baobabs (*Adansonia digitata*) and the palms *Hyphaene coriacea* and *Phoenix reclinata*.

Crab catchers work in the mangrove channels and each fisherman may harvest 20 kg of crabs daily which are then transported for sale in Malindi and Mombasa. Mangrove cutting for construction purposes was observed in the area near Shekiko Camp.

Sand dunes

Extensive areas of coastal sand dunes, aligned approximately NE-SW, lie along the seaward margin of the Tana Delta. The woody vegetation cover is relatively heavy at about 70% (Ecosystems, 1985); *Balanites* sp., *Dombeya* sp., and *Grewia* sp., form a thick shrub layer while common tree species include *Hyphaene coriacea, Hyphaene compressa, Garcinia livingstonei, Euphorbia candelabrum* and *Afzelia guanzensis*. *Ipomoea pes-caprae*, a creeping vine, forms a dense mat seaward above the high water mark.

Coastal waters

The vegetation of the coastal water off-shore of the Tana Delta has not been investigated. In Ungwana Bay, heavy trawling activity takes place along with the activity of small fishing vessels. The main types of fish caught are prawns, sardines, scavenger fish, rabbit fish, mullets, sharks, rays, snappers and parrot fish (Kithome, pers. comm.).

Recommendations

The proposal to create a Tana Delta National Wetlands Reserve, to protect a major part of the Tana River Delta and its flora and fauna, has been presented to the Tana River Delta District Development Committee and should be supported and implemented.

A careful study to understand the human and ecological aspects of the delta environment should be undertaken. This study would include a comprehensive assessment of both the natural and human resources as well as current activities. An education campaign to create public awareness on the value and problems of the delta ecosystem needs to be launched.

The target groups in the delta management strategy are the traditional agriculturalists, the pastoralists and the fishermen. Land use plans must take into account the opportunities for expanded traditional agriculture, the needs of pastoralists and the improvement of the fishing industry. In addition, land-use alternatives which will absorb the growing human population and maintain the ecological character of the wetland, such as tourism, must be considered.

The Tana River Delta has the potential to become a model project for the compatible management of traditional human activities together with conservation. A management board is required to co-ordinate and integrate the various land-use practices in the whole delta. This board should have representation from Lamu, Tana River and Kilifi Districts. A management plan is required for the delta and must be implemented in co-operation with the local people to ensure it is compatible with their needs and contributes to improving their living conditions.

Finally, it is recommended that plans to expand the Tana Delta Irrigation Project (TDIP) should be rejected and that no group ranch or prawn farm should be established within the boundaries of the proposed Tana Delta Wetlands Reserve. Any new development project in the delta should be preceded by a thorough Environment Impact Study (EIS).

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Utilisation and conservation of wetlands: an agricultural drainage perspective

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Summary

This paper is concerned with the fundamental issue of how to accommodate drainage development within the context of environmental conservation and land improvement. Wetland drainage usually takes place because population pressure and associated food scarcity has forced the development of new agricultural lands. Such drainage projects have both positive and negative impacts, however, the negative impacts may be ameliorated if sustainable approaches are used. Many development projects are constrained by inadequate preparation, lack of understanding of social and environmental issues and a shortage of technical expertise. Further research on the effects of wetland drainage is needed.

Target areas

Wetlands can be classified under several categories according to their biological and physical characteristics. The main categories include estuaries, open coasts, floodplains, freshwater marshes, lakes, peatlands and swamp forests. Wetlands are heterogeneous land units offering diverse benefits and experiencing different levels of human interference. Since drainage is undertaken to improve agricultural productivity, the areas targeted for drainage are marshes and swamps with soils suitable for agricultural production.

Agricultural drainage, in its broadest sense, refers to the operations necessary to reclaim the following classes of wetlands:

- lands which absorb an excess amount of water and have inadequate sub-surface natural drainage;
- lands which are subject to excessive surface water accumulation with inadequate natural surface drainage, such as flat lands with relatively impermeable soils;

- lands which are subject to flooding from the outflow of rivers and from the runoff of adjacent areas;
- lands waterlogged by irrigation;
- lands which are unproductive because of an excess of salts.

Drainage interventions are intended to supplement natural surface and sub-surface drainage with the objective of preventing the accumulation of excess soil moisture within the desirable depth of the root system of crop plants.

The challenge

The marshy and swampy lands of Kenya are quite diverse and their ecological and socio-economic functions include: providing vital habitats for resident and migratory birds, fish and other animals; playing a role in preservation of the quantity and quality of water resources; providing plant materials for a variety of uses and cultural values.

As the population increases, so does the demand for utilisation of swamps for agricultural production. In some parts of Kenya, swampy land has been put into sugar cane and rice production and farmers have reclaimed poorly-drained valley bottoms for other crops.

Although wetland development for agricultural production is progressing at a rapid rate and many beneficial effects are being recorded, the environmental impacts of some projects have not been what politicians, planners, drainage professionals and land-users had expected. A case in point is the Kisii Valley Bottom Drainage Development that resulted in rapid degradation of peat soils and subsequent loss of agricultural production (Government of Kenya, 1986). Such serious problems, emerging from time to time, have drawn attention to the fact that reclamation of wetlands for crop production yields a mixture of desirable and undesirable effects. It has therefore become clear that there is need to take into account the complex inter-relationships between people, land, water resources, environment and development.

Agricultural drainage

Historical development of drainage in Kenya

Agricultural drainage is a relatively new activity brought about by increasing population pressure on scarce land resources and the farmers' realisation of the potential of wetlands for increasing agricultural production. During the colonial era, cultivation was confined to the good lands and wetlands were generally used as water sources and dry-season grazing areas. During the late 1950s and early 1960s, some white settlers made raised beds which enabled them to avoid water-logging and grow wheat in the poorly-drained areas of Nyandarua District (Central Province). In Kisii District (Nyanza Province), one of the most densely populated areas of Kenya, food scarcity forced farmers to begin reclaiming the valley bottoms in the 1970s (Muya, 1985). Farmers in the Central Province have been utilizing the valley bottoms for production of arrowroot for a long time.

In the late 1970s, an Irrigation and Drainage Research Project was established with technical and financial support from the Netherlands Government. The project prepared guidelines for valley bottom development in Kisii District and basin development in Ndeiya-Karai (van der Wal, 1979 and 1980). The broad objectives of the proposed drainage development were to:

- increase the area suitable for agricultural production for the benefits of smallholder farmers;
- create employment opportunities in the area during the construction period and thereafter as a result of increased agricultural activities;
- protect the existing water regimes downstream against the risk of inappropriate spontaneous valley reclamation by surrounding villages;
- generate experience and know-how that could be used for future drainage programmes.

From the late 1970s, many large-scale cooperative and settlement farms were subdivided, often without adequate consideration of land-use, carrying capacity or environmental degradation hazards. For example, in 1982 Lelmolok Settlement Farm was subdivided and approximately 70 families were each allocated 2 ha of poorly-drained land (Michiemo and Mugwanja, 1987).

Self sufficiency in food and improved living standards of the rural people have been the main reasons for increased government and donor support for irrigation and drainage development. The scarcity of high potential land and the rapidly increasing population have been the main forces behind utilisation of the wetlands.

Positive impacts of drainage

The potential for development of waterlogged areas with soils suitable for agricultural production ranges between 30,000 and 50,000 ha. These poorly-drained areas have traditionally been used for grazing by large-scale farmers on a communal basis. Due to population pressure and the scarcity of good agricultural land, wetlands are presently being turned into areas of cultivation and settlement.

Drainage is undertaken to reclaim waterlogged land, to improve productivity of crops and pastures and to change the farming system from low value to high value crops. There are few farmers who would dispute the benefits of drainage as they include a wide range of factors which improve crop, livestock and farm operations.

Drainage improves germination and allows earlier crop establishment. A well-drained soil allows crops to establish a good root system to utilise the soil nutrients and fertilizers. The development of healthy plants reduces the risk of disease and pest attack thus increasing yield. In Lelmolok, maize yields were reported to increase from zero on poorly-drained land to 2,400 kg/ha with proper drainage (Michiemo and Mugwanja, 1987). After drainage, crop yield increases of between

10-100% can be expected for most crops, depending upon the initial drainage status of the land.

Livestock may benefit from land drainage by reduced damage to the soil surface which results in maintenance of the productivity of the pasture and an increased length of the grazing season. There is a reduced incidence of animal diseases and foot problems associated with wet pasture. In Wanjohi area, the farmers reported that most of their livestock were infested with liver fluke. If (on average) four wetland-raised cattle are slaughtered per day and if 75% of the livers are rejected due to liver fluke, a loss of approximately KSh 100,000 would be incurred annually. Farmers report that medications are expensive and time-consuming to administer. Thus improving the habitat by drainage is a long-term solution to losses from liver fluke.

Drainage improves the working conditions of farm machinery with savings in fuel consumption, increased output and increased number of work days per year. Socio-economic benefits include creation of employment and improved food and cash supply.

Negative impacts of drainage

The negative impacts of agricultural drainage can be divided into three main categories; environmental, hydrological and socio-economical. These impacts are difficult to quantify in monetary terms, making it problematic to compare the positive and negative impacts of drainage development using the same units of measurement.

Environmental impacts

Drainage causes a decrease in the number of species of wetland plants that are of scientific, economic (medicine, mats) and scenic value; wildlife species decrease and waterfowl change their migration patterns. Cultivation and an increase in channel flow velocities may lead to soil erosion, while over-draining of organic soil results in oxidation of organic matter and general degradation of the soil resource. Agricultural practices may increase the quantity of agricultural chemicals reaching the streams, rivers and lakes which could result in eutrophication.

Hydrological impacts

A decrease in the valley bottom functions of regulating the fluctuation of stream and river discharges and ground water storage are examples of hydrological impacts. Natural wetland vegetation traps silt in water flowing through it; removal of this may increase the amount of siltation downstream (Muthuri, 1989). There may be a reduced availability of water for human and livestock consumption.

Hydrologic effects of draining swamps and marshes depend on the geology, topography, climatic conditions and level of drainage. It is important to ensure that the wetland and its associated catchment are thoroughly studied to determine the specific role that the wetland plays in regulating hydrological phenomena and to assess the human values of these hydrologic regulations. Reduction of any area of free transpiring vegetation can be expected to reduce water loss through evapotranspiration. Under such conditions the hydrologic effects of draining marshes would be a gain in quantity of water with some loss in regularity of seasonal flow. If the marsh is fed by seepage from springs, the springs may already be controlling the flow rate. This would also be the case if the runoff coefficient of the contributing catchment was very low. Studies in Gachuva Catchment in Kisii District indicated that the catchment area has a very high buffering capacity resulting in only 3.1% of the rain being turned into direct runoff (Government of Kenya, 1986).

Drainage may have very little effect on the hydrologic regimes when there is adequate catchment protection leading to low amounts of direct runoff. Catchment protection should also ensure that when the main source of river flow is ground water, this should not be intercepted by drainage channels.

Socio-economic impacts

Socio-economic impacts are related to the environmental and hydrologic impacts above. They include an increase in the energy expended to obtain a unit of water as a result of drainage intervention and lowering the ground water resources, thus reducing the availability of surface water during the dry season. Downstream flooding may increase, resulting in destruction of crop land and farm land infrastructure. Drainage canals may form breeding grounds for disease-carrying vectors and increased human activities in the drained area may elevate the health risk.

Sustainable wetland development

Technical options

There are several options available for utilisation of poorly-drained areas; the choice is based on physical suitability, expected benefits, farmers preference and environmental impacts. The options are not exclusive of one another but may be complementary and in the long run mutually reinforcing.

Adapting crops to existing conditions

Crops that can withstand wet growing conditions should be introduced, thereby deriving a higher economic return than the low value utilisation of wetland vegetation for grazing and other uses. Suitable plants include rice, aquatic fodder (water *Ipomoea*) and swamp *Cyperus* (van der Wal *et al.*, 1978). This has minimal disturbance on the natural environment and hydrologic regime.

Fish and duck farming

In areas with adequate water supply throughout the year, fish and/or duck farming ponds could be constructed. Fish farming is currently being promoted in Western Kenya and duck farming has been practised for some time in Kirinyaga District (Central Province).

Low intensity drainage

Different land-uses require different levels of water control; with low intensity drainage, excess water is evacuated only during the most critical period. This is generally accomplished by construction of shallow and narrow drains. Land thus drained can be planted with species that can withstand periods of waterlogging such as some pasture species or food crops including rice, finger millet, sorghum, local beans, cow peas, cassava and sweet potatoes. Such land can also be used for tree planting.

High intensity drainage

This method implies total control of the soil moisture regime in the crop root zone. It requires the construction of a dense and deep system of drains and a high level of investment; therefore it is economical only when high value crops are grown. In certain conditions additional land improvement measures might be feasible and economical such as sub-soiling to improve the internal drainage of the soil and complete soil water control by irrigation during the dry season.

Environmentally sound development

The worldwide decline in environmental quality has led to increased pressure to include environmental protection as an objective, in addition to economic and social objectives, in development projects. To ensure that all aspects of environmental impacts are addressed, Environmental Impact Assessments (EIA) should be incorporated as part of drainage development feasibility studies. An EIA should identify and predict likely impacts, interpret and evaluate the relative importance of such impacts, advise on the environmental feasibility of the project and identify mitigation measures as well as monitoring and evaluation requirements.

Systematic monitoring and evaluation of drainage projects is important and should determine the extent of the achievement of project goals by assessing actual, compared with predicted, impacts. Information should be gathered on reasons for not attaining goals. Such studies should increase management's understanding of the various interlinked processes and issues to improve the planning, implementation and management of similar projects (Biswas, 1988).

Constraints

A voluminous literature exists which has analysed some of the major constraints to successful implementation of sustainable land and water development projects. Constraints of environmental impacts on water development projects are often closely related and include the following:

- incomplete framework of analysis;
- lack of appropriate methodology;
- inadequate knowledge base;
- institutional constraints;
- absence of monitoring and evaluation as part of the management process;

- inadequate extension and technical support;
- changes in land-use in the catchment area;
- failure to involve the beneficiaries throughout all the stages of the project;
- increasing land pressure and food shortage that drives farmers to short-term gains at the expense of sustainable development;
- farmers' unwillingness to accept less paying options of land-use intensification and/or new ways of land-use intensification (fish and duck farming);
- farmers' reluctance to cope with additional workload.

Research needs

There has been very little research undertaken in Kenya to study the effects of draining wetlands for agricultural production. Studies carried out include a pilot study of hydrology, soil preservation, agro-economy and valley management in Kisii Valley bottoms (Government of Kenya, 1986) and a surface water management study of Lelmolok Farm (Michiemo and Mugwanja, 1987). No study has specifically addressed the issue of environmental impacts of drainage intervention.

Thus the controversy over utilisation of wetlands for agricultural production stems from limited understanding of the processes of wetland ecosystems and how adverse impacts can be minimized or eliminated. The economic, social and environmental costs and benefits of draining wetlands must be defined. Optimal allocation of land to cultivation, grazing and environmental protection should be researched and recommendations made for the preservation of wetlands for their environmental value. Presently the optimal buffer strip for filtering silt and removal of nutrients to reduce the danger of eutrophication of downstream waters is not known. Policies which discourage destruction of wetland ecosystems in favour of cultivation need formulating.

Conclusion

Wetlands are among the most productive and fragile ecosystems. Their profound importance to both humans and wildlife calls for a concerted effort in ensuring their sustainable utilisation. Attempts should be made to promote sustainable development of such wetlands with adequate consideration being given to human and environmental requirements.

The status of swamps and marshes in Kenya should be viewed in the context of their role in the economics of the nation, the local community and the individual. From a national perspective, the area may be looked upon as a water catchment or habitat of endangered plant and/or animal species that needs preservation at all costs. From the community point of view, the area may be considered a breeding ground of snails and mosquitoes or as a vital source of water during the dry season.

From an individual's point of view, the swamp may be considered a hinderance to development or as a vital dry-season grazing area. Such contradictions make it difficult to decide whether to utilise or preserve a particular wetland.

Thus the major question confronting policy makers, politicians, environmentalists and drainage professionals is whether to convert some of the swamps into agricultural fields. Experience has shown that preservation of wetlands is very difficult to achieve in areas where there are critical short-term problems such as population pressure, malnutrition, diseases, high infant mortality, low life expectancy and chronic unemployment. The only choice is therefore sustainable utilisation and conservation of these vital resources.

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Wetlands and water supply in Kenya

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Summary

The Kenyan Government's policy is to supply adequate water to all the entities of Kenyan society to improve the quality of life. Due to man's desire for ultimate joy and comfort, water, being one of the nature's free resources, is continuously being exploited or used by various national and economic-potential sectors such as agriculture, industry, domestic use, recreation and in hydroelectric power generation. Wetlands have been a main resource of water supply in Kenya. With rapid increases in population, urbanization and industrialization, the huge demand for water has stressed wetland areas. This developmental change, if not managed, may continue to stress wetlands and in the process, alter the quality and quantity of the resource base.

Introduction

Water is life! It is the most vital, natural resource for man's survival. Hence adequate and safe water must be guaranteed in the process of building a strong and healthy nation. At the time of independence in Kenya, water had to be fetched from distant sources: it is the Government's policy that potable water should be available within 4 km of every homestead by the end of the century.

The target is not easy but it is attainable. There are difficulties in reaching this target and great efforts are needed to overcome obstacles, both natural and man-made. In areas with hilly topography, people are often forced to travel long distances to get water; in some cases people depend on water collected in man-made ponds.

Various programmes for the supply of water in both rural and urban settlements have been initiated, but the major constraints to implementation are the lack of financial resources and technical needs. Apart from the Ministry of Water Development and local authorities, NGOs and community organizations have been involved in water supply and related projects.

Population projections

Population projection is an important tool for predicting domestic and livestock water demands both in rural and urban centres. Natural population projections indicate that in the year 2000, Kenya's population could be 34 million (JICA (Japanese Aid Agency), 1990). The urban *per capita* use of water is far higher than that for rural areas (Table 1). In 1979, about 15% of the population lived in towns and cities while by the year 2000 the urban component is expected to be 26%. As the human population increases, so does the need for more livetock (and its associated water requirement). However, the presently used management techniques for Kenya's livestock may prevent a substantial increase in numbers as the available grazing areas are almost saturated already.

Water demand

Table 1 shows the estimated daily water consumption rates for livestock. In urban areas, 50% of water consumption is for domestic use while, of the remainder, 15% is commercial, 9% industrial, 9% public and 17% is unaccounted for.

Rural consumers rarely use more than 15 litres/*capita* from traditional sources; this figure may not increase in the future. Where water supply systems exist in rural areas, consumption at communal water points is affected by climate, distance, traditional source and availability. The consumption of rural individual connections is expected to rise from 70-100 litres/*capita* between 1978 and 2008.

It is assumed that livestock within areas covered by water schemes will be watered from that supply. In this case, animals have a 25% higher consumption than animals using traditional water sources (JICA, 1990).

Table 1 Estimated daily water consumption in Kenya, 1978 (JICA, 1990)

	(litres/day)
Rural traditional source consumers	15
Communal water point	25
Rural individual connection	70
Local cattle	30
Grade cattle	95
Small stock	5
Urban domestic	
Nairobi/Mombasa	160
Major towns and urban centres	140
Rural centres	100

Estimation of water requirements in urban centres is a complex exercise because it is difficult to estimate the rate of growth of industry. High water consumers, such as the tourist industry, present problems of prediction in the future and population changes due to rural-urban migration are equally uncertain. It is generally assumed that the industrial and commercial sectors will grow in proportion to the GDP (gross domestic product).

Water balance

Natural water balance (without abstractions) is estimated basin-wide from rainfall, runoff and evapotranspiration. The latter may be estimated indirectly by subtracting runoff from basin-wide precipitation (Tippets *et al.*, 1979). Mean annual rainfall is needed to estimate the water available for abstractions such as domestic use, industry and agriculture.

Water development expenditure

The cost of adequate water development between 1981 and 2008 was estimated in 1979 to be Kenyan pounds 10,787 million, at 1979 price levels. This amount was to be distributed as 35.1% to urban water supply, 12.8% to urban sewage, 38.5% to rural water supply and development, 4.5% to dams and hydropower, 3.0% for irrigation and 6.1% on services and infrastructure. However, actual expenditure has been well below recommended levels; in the 1990/91 fiscal year expenditure was approximately 25% of that estimated in 1979.

Main sources of water supply

Water supply in Kenya is mainly obtained from two major resources: surface water and ground water.

Surface water is that part of precipitation which flows overland and through channels to the watershed outlets. Overland flows begin when available interception and depression storage are completely filled and when rainfall intensity at the ground surface exceeds the infiltration capacity of the ground material. This process leads to water flows which end up in the form of rivers and streams.

Kenya can be divided into five major drainage areas for hydrological purposes; Lake Victoria basin, Tana River basin, Athi River basin, Rift Valley basin and Ewaso Ngiro North basin. Abstraction of surface waters from these drainage basins forms the major source of water supply in Kenya. This process is achieved by the construction of dams, weirs (especially in streams) and by using roof catchment, rock catchment or water pans.

Table 2 shows the number of existing large-scale dams and those under construction. Small-scale dams are those less than 15 m in height; the number existing or currently under construction in Kenya is approximately 780.

Ground water resources, in the form of water-bearing rocks (aquifers), are an important source of water supply in Kenya. These consist of three major groups of rock; bedrock, volcanic and sedimentary. Boreholes and shallow wells are the major means of obtaining ground water for use in water supply. Boreholes drilled in volcanic rocks are deepest (125 m) while those in bedrocks are of medium depth (92 m). Not all boreholes are successful due to inadequate yield, poor water quality or diminishing yield. Northern and eastern Kenya are areas with sedimentary rocks and underground water in these regions is of poor quality. Abandonment rates of boreholes is 9.1%, 24% and 21.9% in volcanic, bedrock and sedimentary rock respectively. Table 3 shows the number of boreholes per drainage area and the dependent population.

A problem facing ground water production is the imbalance in the utilisation of financial resources for ground water use as more is invested on borehole construction than on the supporting investigations necessary to estimate the supplies (JICA, 1991 a and b).

Wetlands as water sources

Surface water is a major contributor to water reserves in Kenya. Some of these wetlands (rivers, streams and ponds) are traditional sources of water. Natural wetlands used as major sources of water in Kenya are permanent rivers and streams, temporary streams, ponds, dams (water supply and hydropower) and freshwater lakes.

Pans and dams are the artificial wetlands which have been created to boost the supply of water for irrigation, domestic and industrial purposes. More artificial wetlands will be created in future to meet the continual demand for safe, potable water.

Quantity and quality of wetland waters

The quantity of wetland waters is influenced mainly by seasonal climatical changes. The amount of rainfall determines the discharge, especially in streams and rivers. Lake levels rise during the rainy seasons. The same phenomenon applies to small or large dams as the level of water in them fluctuates throughout the year, depending on the extent and amount of rainfall and the runoff it generates.

The quality of surface water is very important for human consumption. The concentration of ions varies from one drainage area to another. Various factors could be attributed to this such as bedrock formations, climatical factors (rainfall and temperature) and human activities in the catchment areas.

Table 2 Distribution of large-scale dams in Kenya

Drainage basin	Existing dam	Under construction	Detailed design	Feasibility study	Master plan	Total
Lake Victoria	3	2	1	3	5	14
Rift Valley	1	2	2	4	2	11
Athi River	6	1	1	4	4	16
Tana River	6	1	0	3	4	14
Ewaso Ngiro North	0	0	0	1	3	4
Total	16	6	4	15	18	59

Table 3 The distribution of boreholes in Kenya's drainage basins and the populations that they serve (1979)

Drainage basin	Area km^2	Population size	Number of boreholes	km^2/ borehole	Persons/ borehole
Lake Victoria	46,021	6,015,000	435	105.8	13,828
Rift Valley	124,722	1,303,000	771	161.8	1,691
Athi River	66,520	3,644,000	2,108	31.6	1,729
Tana River	126,827	3,007,000	328	386.7	9,169
Ewaso Ngiro	209,320	762,000	587	356.6	1,298
Total	573,410	14,731,000	4,229		
Average				135	3,483

Water is also an effective means for transporting pathogens, and water-borne diseases are a major cause of sickness. Coliforms are used as indicators of water contamination as they survive in natural waters, especially in tropical climates. Current guidelines on the quality of drinking water include recommendations on aesthetic, inorganic chemical, organic chemical and bacteriological aspects.

Conclusion

It is worthwhile noting that wetlands are our major resource base in the development of water supply. Our developmental efforts in various sectors of our economy rely to a great extent on water. Population and economic growth are some of the main factors that exert pressure on this limited resource. It is, therefore, important to consider wetlands with great care, knowing that their over exploitation will be detrimental to our development effort to improve our quality of living.

Wetlands must be conserved for our development. The depletion, degradation and deterioration of water must be monitored in all aquatic processes in Kenya. Hence all the water bodies or wetlands which are subject to exploitation must be conserved or protected against processes that erode and pollute.

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Agricultural chemicals and wetlands: a review

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Summary

Pesticides and fertilizers used in the agricultural industry are major sources of pollutants of water through leaching or runoff. In wetlands, these pollutants could have serious adverse effects on the diversity and productivity of the biota. In Kenya, wetland ecosystems that are threatened by increasing agricultural activities include the coastal mangrove belt, inland lakes, rivers, and marshes. Apart from being sources of chemical pollutants, agricultural activities may also encourage soil erosion, thereby contributing to the problems of water turbidity. Degradation of wetlands could cause havoc to resident or migrating birds and other animals. Further reclamation of wetlands for agricultural production could increase the chances of poisoning the fauna.

Introduction

Wetlands are found in the bottom of river valleys, land depressions, lake perimeters and coastal areas. These ecosystems are influenced by many factors, including human activities within the catchment areas such as agricultural production.

Modern agricultural practices make use of large amounts of fertilizers, soil conditioners and pesticides to enhance productivity. Unfortunately, however, these chemicals and organic materials have the undesirable effect of polluting water systems including wetlands, through runoff from cultivated land. Accumulation of these pollutants in wetlands may poison flora and fauna, thereby upsetting the established ecological balance.

Little or no research has been conducted in Kenya on the effects of agrochemicals on wetlands, possibly due to the fact that no catastrophic pollution of a wetland ecosystem has yet been experienced. However, continued pollution of our rivers, lakes, wetlands and coastal waters needs to be monitored. Experience from countries which have suffered from water pollution problems suggests that disappearance of animal and plant species from polluted wetlands occurs (Nature Conservation Council, 1982; Briggs and Courtney, 1989).

In Kenya, some wetlands are found in areas with little agricultural production around them, particularly those found in arid or semi-arid areas such as the Lorian Swamp and seasonal Lake Amboseli. However, some of the rivers draining into these wetlands pass through agricultural areas where they pick up agricultural chemicals. Other wetlands are found in areas of high agricultural potential such as those around some inland lakes, rivers and marshes. The coastal mangrove swamps are exposed to pollution by agricultural chemicals due to the intensive agricultural activities in the upper and lower catchment.

Fertilizers and soil conditioners

Many agricultural soils are deficient in certain plant nutrients which must be added to the soil to enhance its productivity. These nutrients include phosphorus, nitrogen and potassium; they are added to the soil as phosphate and nitrate salts of calcium and ammonia or as potassium chloride. Kenyan farmers use more than 300,000 tonnes of fertilizers per year (Central Bureau of Statistics, pers. comm.).

Soil conditioners are added to soils to ameliorate soil structure or to improve the chemical environment of the soil, particularly by adjusting the pH to levels desirable for optimum plant growth. Calcium carbonate, magnesium carbonate and calcium sulphate are extensively used for this purpose.

These chemicals may find their way into water systems, including wetlands, and become pollutants. Continued accumulation of such chemicals in wetlands can seriously upset their ecological balance.

Acidity

Pollutants accumulating in wetlands may cause changes in pH values of the water depending on the nature of pollutants and the pH-buffering capacity of the wetland. The pH would be expected to increase if the polluted runoff originates from calcareous soils or if the runoff contains liming materials leached from the soil. If the runoff is from acid soils, or if the recently added fertilizers are the acid-forming type, the water pH values would be expected to decrease in wetlands downstream.

Under normal circumstances, the water in wetlands has a pH value below six due to the accumulation of organic acids, as well as the chelating of heavy metal ions by organic matter or their precipitation as metal sulphides. The ideal pH for optimum growth of most micro-organisms and macrophytes, as well as for animal life in wetlands, is usually between pH 6 and pH 7. When the pH values fall below this range, the availability of some nutrients such as calcium and potassium becomes limiting. The availability of phosphorus and trace elements may reduce with increased pH.

Drastic changes in the pH of a wetland could give rise to a total collapse of the whole ecological system. Gosling and Baker (1980) reported a sudden change of pH from a near neutral value to about pH 3 for a wetland in the English Midlands. All the fish and mussels died as well as most algae and macrophytes. An opportunistic acidophilous algae *Tribonema urius* took advantage of the situation and invaded the wetland. The cause of the sudden change of pH was traced to agricultural activities in the surrounding areas; draining of adjacent land lowered the water table surrounding the wetland and the pyrites-rich sediments were oxidised to sulphuric acid.

Nutrients

Wetlands are usually poor in plant nutrients and the biota they support has the ability to survive under such conditions. However, when nutrient status is enhanced by accumulation from farmlands, other floral communities may appear as the new system supports much higher biomass production. At first, there is a rapid increase in algal blooms followed by an increase in macrophytes. The eutrophication process leads on to accumulation of dead organic matter in the water, mostly from the rapid turnover of algal blooms. Dissolved oxygen is rapidly depleted with catastrophic consequences on the vulnerable flora and fauna. Microphytes, fish and other fauna are generally very sensitive to low levels of dissolved oxygen in water and so these communities are quickly eliminated from the ecosystem. Macrophytes, which can absorb oxygen from the air, through the leaves and transfer to the roots, then begin to dominate.

In recent years the proliferation of algal blooms of *Chrysochromulina polylepis* (red tides) in the North Sea coastal areas has become a formidable environmental problem. Nutrients from agricultural lands and from sewage sludge dumped into the sea have been identified as the cause of red tides. Mass deaths of whales, dolphins, seals and fish during the last few years have been attributed to this problem. Some microphytes, which thrive at higher nutrient levels than non-toxic varieties, produce biotoxins which accumulate in fish and cause the death of the fish and their predators (Dietz *et al.*, 1989; Underdal *et al.*, 1989). In the coastal waters of Eastern Africa, Bryceson *et al.* (1990) contend that the nutrient status is, so far, low and the destructive red tides are no problem. In fact they further argue that the level of nutrients is likely to be below the desired levels for optimum productivity of the Eastern African coastal waters.

In Kenya, important wetlands which are exposed to agricultural chemicals include some Rift Valley lakes, the Yala Swamp and mangrove swamps along the coast.

Lake Naivasha is surrounded by rich farmlands which are under intensive cultivation for production of vegetables and cut flowers. The runoff from these farms, which is rich in fertilizers, flows into the lake. This freshwater lake is periodically invaded by floating masses of *Salvinia molesta* that could threaten the survival of other flora and fauna in the lake. It is suspected that the nutrient supply from the surrounding farms, along with favorable weather conditions, contribute significantly to these blooms. Urgent research work is needed to determine factors which influence the ecological balance of the Rift Valley lakes and their surroundings.

The Yala Swamp lies at the outfall of Nzoia River at the edge of Lake Victoria. This river drains extensive agricultural lands which are intensively cultivated. The river is therefore likely to carry appreciable amounts of agricultural chemicals which could cause eutrophication of the swamp. The swamp forms an important breeding ground for lake fish and is a habitat for many water birds including cranes, herons and geese. Continued accumulation of plant nutrients could adversely affect the biota. The reclaimed part of the swamp is used for growing sugar cane, rice and other food crops which require appreciable amounts of fertilizers, soil conditioners and pesticides. There is a need to monitor the accumulation of chemicals in this area.

Irrigation schemes usually attract water birds, thereby exposing them to the chance of poisoning by agrochemicals. Recent deaths and deformities of birds in the USA have been blamed on trace metals (Anderson, 1987).

Pesticides

Modern agricultural production relies heavily on chemical control of plant pests and diseases. Kenya uses about 7,000 tonnes of pesticides per year (Pest Control Products Board, pers. comm.). Some pesticides are applied to the seeds before planting, others to the crop foliage. They are also used for control of livestock pests in dips, spray races or hand sprays. Such chemicals may find their way into wetlands through runoff or by leaching through the soil profile. Use of chemicals to control weeds along irrigation canals can be another source of wetland pollution. Continued accumulation of these chemicals in wetlands can have adverse effects on the established ecological balance, including the disappearance of some species of flora and fauna (Brown, 1978).

Herbicides can be very destructive to the plant life of wetlands, including those algae which are the base of the aquatic food chain. Algicides include 2,4-dichlorophenoxyacetic acid (2,4-D), monochlorophenoxyacetic acid (MCPA), diquat, paraquat, simazine, triazines, acrolein, dichlobenil, maleic anhydrazide, glyphosate, substituted ureas, dalapon, simetryn and fenetin. One of the most popular herbicides for clearing weeds from irrigation canals is 2,4-D which destroys broad-leaved weeds. This chemical has, therefore, the undesired effect of upsetting the balance of plant life in wetlands by favoring grasses at the expense of broad-leaved plants.

Herbicides are generally less toxic to animal life than insecticides, although a few herbicides - paraquat, diquat and cresols - are toxic to aquatic fauna. Paraquat is particularly toxic to fish and birds; in recent years this herbicide has been blamed for poisoning domestic animals which have drunk from dams and streams contaminated with runoff from wheat farms. This chemical is widely used in Kenya.

Insecticides are generally much less toxic to aquatic plant life than to fauna. Organochlorine insecticides are more toxic to aquatic fauna, especially fish, than organophosphorus insecticides. Moreover, the latter have relatively short half-lives which makes them much more acceptable to environmentalists. Among the organochlorines, the cyclodienes (e.g. endrin) are the most toxic to aquatic fauna.

DDT is less toxic than cyclodienes but the higher bio-accumulation rate of DDT may cause the death of predators. Although most organophosphorus insecticides are environmentally more acceptable than organochlorines, there are a few organophosphides (parathion, ethion, azinphos-ethyl) which have long half-lives and are very toxic to wildlife. It should also be noted that while phosphorus compounds with a -P=S group have generally low toxicity, their metabolites which may contain the -P=O group can be very toxic.

Other insecticides that are toxic to aquatic fauna, but which have limited persistence in the environment, include the carbamates, which are highly toxic to invertebrates, and the pyrethrins, which are very toxic to fish.

A special category of pesticides which are environmentally unacceptable are the metallic-based compounds of copper, mercury, arsenic and manganese. These pollutants are not biodegradable and once in the ecosystem will remain there. If they are allowed to accumulate in wetlands they can completely destroy some vulnerable biota. In Kenya, the metallic-based pesticides used are copper compounds, particularly copper oxychloride which is used as a fungicide and, to a lesser extent, manganese compounds. Copper-oxychloride is also used to ameliorate copper deficiency in wheat-land soils in the Rift Valley Province. Although copper is an essential nutrient both for plants and animals, in excess amounts it is toxic to both. The autotropic algae that grow in the Rift Valley lakes and provide food for flamingos and other birds in the area could easily be poisoned by accumulation of copper in these lakes. For this reason a plan to build a factory to manufacture these copper compounds in Nakuru was successfully opposed by conservationists. However, the farmers in these areas continue to apply copper compounds to their fields and there is, therefore, a need to monitor the accumulation of this pollutant in the lakes.

It should be noted that poisoning of wildlife by pesticides brought into wetlands from farmlands is mainly confined to persistent pesticides, such as organochlorines. However, it is possible for other less persistent pesticides to poison wetland birds when they search for food. In Spain, tens of thousands of waterfowl were killed in Donana Park after the adjacent rice fields were sprayed with methyl parathion to control crayfish (Mackenzie, 1986).

In Kenya poisoning of birds by pesticides sprayed onto crops is a very common occurrence, although not documented. The major pesticides that are to blame include carbofuran, parathion, endrin, aldrin, azinphos-ethyl, azinphos-methyl, demthion and dicrotophos. Some of these pesticides (parathion, endrin, aldrin) are being phased out because of their toxicity and persistence in the environment.

Conclusion

The amount of agrochemicals used every year in Kenya is rising rapidly. In order to prevent these chemicals from destroying or upsetting the ecological systems of wetlands adjacent to farming lands, there is a need to screen the chemicals in use. Research and programmes to monitor the accumulation of these chemicals in wetlands should be initiated.

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Wetland and dryland management

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The role of wetlands

Wetland and dryland management has recently become important due to population pressure as Kenya's highly productive arable land is limited. In order to maintain food security, the need has arisen to look for additional areas for crop production. Wetlands are potentially attractive and almost immediately available, some are well-watered and fertile lands apparently waiting to be reclaimed and converted into farmland. This outlook has led to little regard for the crucial role played by wetlands in terms of the ecological jigsaw puzzle between river systems, wetlands, lakes and any other zones on which they impinge.

It is recognised that wetlands which contain a mat of closely growing vegetation such as reeds, grasses and water plants act as a biological sieve which traps river sediments. Wetlands are also key players in the natural purification of polluted rivers. They slow down the flow of water as a river meanders in and out of the wetlands on its way into another river or lake. The slow flow causes materials to be deposited as detritus in the wetlands.

Wetlands function as a natural storage for water; vegetation may reduce the rate of evaporation allowing reasonable discharge of water into rivers and lakes. Since the water in wetlands is often very shallow, it is saturated with dissolved oxygen. This provides optimum conditions for biodegradable matter to be broken down by aerobic means before it enters a river or lake. Swamps decrease the salinity of influent water, especially during periods when the flow through is reduced. Wetlands are associated with waterborne diseases as well as vector borne diseases like bilharzia and malaria.

In virgin wetlands a biological survey yields a wealth of species of animals and plants which need to be preserved. The high level of nutrients for the microflora and microfauna which form the basis of the food web found in wetlands. Some fish species migrate into a wetland for the purpose of breeding, but spend the rest of their time in rivers and lakes. Many aquatic birds nest in the wetlands while several mammals, such as the waterbuck and hippopotamus, are associated with the wetlands and lakes. Many bird species are commonly found in wetland ecosystems, including various wading birds such as herons and ibises.

Wetlands of Kenya

Kenya's wetlands vary from the floodplain grasslands, which are abundantly covered with vegetation, to swamps with areas of open water surrounded by flooded vegetation. Wetlands occur in floodplains of various river systems as they flow over flat plains. When the wetland is heavily treed it is called a swamp forest.

In the arid and semi-arid lands (ASAL) of Kenya, swamps are seasonal in nature and vary in size over the year, for instance the Lorian Swamp may vary in area from nil to approximately 5.8 km^2. These wetlands are the vital fallback for dry-season grazing; they provide a sanctuary for the nomadic herds which are driven long distances to escape drought. The wetlands are, therefore, strategic to the ASAL population since they allow the wet season herbs to be sustained without necessarily being cropped. It is not surprising that wetlands and dry-season grazing areas are a source of ethnic conflict among the nomads. It is against that background that a policy on the management of wetlands should be formulated.

Wetlands have been encroached upon by farmers who are seeking land for agriculture, due to population pressure. Wetlands which are associated with river systems in the high agricultural potential areas have dwindled on this account. Although there exists provision in the Agricultural Act for river reserves, this law does not apply to wetlands. Some wetlands have been appropriated to private lands and reclaimed; a good example of this is the Manguo Swamp outside Limuru town, which formed the source of Ithanji River, but no longer exists.

Little is achieved by a cost-benefit analysis of preservation against development of wetlands. It is difficult to place a price on an environmental programme of conservation but sound management of a river system, which entails conservation of its catchment zones and preservation of river reserves, cannot ignore the wetlands.

There are certain large wetlands like the Lorian Swamp, the Tana Delta wetlands and the Yala Swamp which are very important in terms of potential for use. Wetlands are used for pastoralism, crop farming and wildlife management. In the traditional practices of the Orma and Pokomo, both crop farming and livestock co-exist alongside wildlife, but this is threatened by large ranches which interfere with the pastoral and migratory routes of livestock and wildlife. Conflicts arise as wildlife may cause damage to crops, livestock and man.

Kenya ratified the Ramsar Convention in 1990; the convention aims to preserve the flora and fauna of wetlands. This area of environmental management needs to be amplified both in terms of policy and legal support. The ministry would like to see a compromise between farming and conservation activities such that the ecological balance is maintained. Funds from tourism, say bird watching, could be used for the care of destitute pastoralists, such as the Pokomos, who have lost their animals and resorted to crop farming on the wetlands.

The drylands

Traditionally, the nomads were dependent on seasonal migration and they seem to have optimised ASAL resource utilisation by enabling the land to run fallow and recover. Through movements of herds from the drier areas to the wetlands and other dry-season grazing areas, the nomads could achieve an ecological balance within the ASAL lands. The present situation is quite different due to the various changes that have taken place and interfered with traditional nomadic pastoralism, such as land alienation and the present land use conflicts.

Dryland or ASAL management in Kenya has seen various approaches from government dating back to the colonial era when nomads resisted colonial domination and their herds were seized or killed as punishment. Land alienation interfered with dry-season grazing areas forcing the herdsmen to subsist on the dryland. This caused severe degradation of the environment, leading to famines and deaths.

Some management approaches were based on the erroneous belief that problems would be solved if the nomads reduced their herds. Others considered that a change to a sedentary life was the solution to development of the nomads, but this idea ignores the ecological balance and the carrying capacity of ASAL. Recently an environmental or integrated approach to development has become the government policy on ASAL development. The Ministry of Arid and Semi-Arid Lands and Wastelands has produced a draft policy for the development of ASAL which emphasizes the integrated approach. This policy is soon to be circulated for debate.

Pastoralism in ASAL regions traditionally involved grazing livestock in areas with temporary water, during and soon after rainy seasons, and utilizing areas with more permanent water in the dry-season. The system has the effect of rotating the grazing pressure and keeping some grass in better condition for dry-season grazing. Some wildlife populations follow the same pattern and use the same areas seasonally. Traditional dry-season grazing areas are the areas of high agricultural potential in the region. They are the isolated higher rainfall mountains within ASAL or along the riverine strips and low-lying alluvial areas. These dry-season fallback areas are coming under increased pressure from cultivators who are either spontaneously settling as they move from higher production zones or are being settled on more organized irrigation schemes. Both farmer-pastoralists and immigrant-cultivators are farming these areas, thus the dry-season grazing areas are decreasing and the remaining marginal areas are coming under greater grazing and browsing pressure.

The extent of land adjudication to individual or group ranch holdings varies from one district to another. In some of the marginal and semi-arid areas, privatisation is well advanced while in most of the drier areas, particularly in the north and northeast, little has occurred. Government policy favours adjudication but this has certain negative consequences especially where wildlife migration and dispersal routes are concerned. Land adjudication does influence the transition to a cash economy and was intended partly to give incentives for resource conservation. In some group ranches this may be so, however, private ownership has also increased settlement, fencing and permanent cultivation. It has also allowed further subdivision into plots too small to be either sufficiently productive or able to conserve soil and water effectively. The resale or lease of former pastoral lands to farmers, sometimes from other regions, has occurred. This has contributed to the conversion of land to cultivation, especially dry-season pastoral areas, and threatens the ASAL livestock economy.

Parts of northern and northeastern Kenya are affected by land use competition between different pastoral ethnic groups or by insecurity. The result is the displacement of groups, with likely increased use of their remaining territory and temporary abandonment of particular areas, leading to intensified land use elsewhere. Isiolo District experienced this problem. This trend, however, can also result in the recovery of range and wildlife resources in the vacated areas.

There has been a gradual expansion of both small-scale and large-scale irrigation schemes in ASAL areas using water from rivers fed by highland catchments. These usually occupy the highly productive dry-season grazing areas and when such areas are turned to crop-production pastoralists are displaced.

Seasonal migration is determined by factors such as topography, climate, water availability, animal diseases and security. If migration is not possible the measures taken to mitigate land degradation include supplementing human and animal food from outside sources, seeking an alternative livelihood, establishment of perennial fodder trees and population growth moderation. If these measures fail, natural control should take place but rarely occurs in our present day global village.

The major problem which stands in the way of ASAL development is the area's inherent lack of water. This problem is compounded by the demographic characteristics unique to ASAL. The population density is low but the carrying capacity is also low; population pressure creates degradation. Other causes of resource degradation are the prevailing market structure in ASAL which results in unfavourable pricing systems for livestock when compared with prices for grain.

The search for new agricultural land, combined with the need for fuelwood, results in an increased rate of devegetation. This in turn leads to soil erosion and lowers the dry-season water table and, combined with reduced fallow periods, leads to declining yields and forces farmers to clear new lands: the spiral of degradation begins once more. This situation leads people to move away seeking more favourable conditions and the rural-urban migration sets in.

Due to limited availability of prime land in ASAL, there is severe competition for this land by major activities such as livestock, agriculture, wildlife and urban sectors. This competition has led to marginalisation of the pastoralists to more arid zones. Although pastoralists are slowly turning to crop agriculture, it may be possible to obtain more food from a given area through combining crops with livestock. Pastoralists should be assisted with marketing of livestock. Other supportive measures, which include improving roads and infrastructure and strengthening institutions, will go a long way towards assuring that development in ASAL is self sustaining.

The strategy for ASAL development should go beyond the conventional focus on individual donor efforts and address the broad long-term interests of Kenya as a whole.

The way forward

The way to avoid further marginalisation of both the ASAL and their inhabitants is to make sure that the mainstay of their economy, livestock, remains stable. It is the only system of production that is compatible with their traditions and it should be supported and made more sustainable.

To sustain the ASAL livestock economy both the arid areas and the wetlands within ASAL must be at the disposal of the pastoralists. For this reason the ASAL wetlands cannot be turned to crop production without threatening the livestock and wildlife.

Food policy and wetlands

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Since its independence in 1963, Kenya experienced a series of years of serious food shortages, which forced the Government to make public appeals to other nations for support. On several occasions, in different years, officials from the highest levels of Government travelled to many countries of the world seeking food aid for national survival.

It was against such an extremely embarrassing backdrop that the Government decided, in 1981/82, to strive for national food sufficiency by mobilizing the national planning mechanism, through the District Focus for Rural Development Policy. Brainstorming sessions were organized across the country and they included District Development Committees and consultants from the agricultural sector.

Two main areas of concern to wetland conservation were discussed. The first, and most critical, was the recognition that more than 75% of the land surface of Kenya was arid or semi-arid and less than 25% of the land held the promise of contributing to this all-consuming and sudden national activity. Suddenly, the planning teams began to think and talk about what it takes to grow food, i.e. good soil and water. They asked: How much rain falls in Kenya? When does it fall? How much is the runoff? What do we have in the form of storage? Are we able to regulate the flow? How large a population do we have to feed? At what rate is that population growing? How is our economy behaving?

The planners discovered that there were deficits in many of the necessities required to produce enough food to make Kenya self-sufficient. As efforts were made to identify which resources were available locally and naturally, frustrations began to strike the planners. They realised that, although Kenya contributed substantial quantities of water to Lake Victoria, under international conventions on shared natural resources she could not extract substantial quantities of water from the second largest freshwater lake in the world. To do this, Kenya would need the explicit legal compliance of the other countries with riparian rights to the lake.

With this in mind, a number of decisions were made, including:

1. to use varieties of drought resistant crops, developed by the Ministry of Agriculture;
2. to encourage landowners, with river frontage, to make every effort to reclaim all the wetlands and swamps that may be adjacent to their land.

It is the latter recommendation which is the concern of this meeting and one that consequently led to the damage of Kenya's wetlands.

Agriculturalists identified rainfed varieties of rice which could grow successfully on such reclaimed lands. In areas where there was deemed to be too much water, Eucalypt trees were planted in large numbers to lower the water table. Thus many rivers and rivulets, which once flowed all year round, have either dried up or at best have been reduced to a seasonal flow. With the advent of swamp reclamation, riverine habitats, and their associated plant and animal species, were either destroyed, with consequent local extinctions, or plant successions occurred which were not characteristic of swamps or riverine ecosystems.

The question which arises is how concerned people, like those at this seminar, may set about trying to rehabilitate some of these changed ecosystems. It is quite obvious that, in cases where extinctions have occurred, there is absolutely nothing that can be done to bring back that which has been lost. It is also obvious that, in extreme cases, the point of no return has been reached. Such a case is in Kisii where the accumulated peat soils were burnt, either during land preparation or naturally, by lightning. In such cases, all we can do is to count the losses.

The efforts to achieve national food sufficiency have also meant the introduction of large quantities of chemical farm inputs, such as fertilizers, pesticides and herbicides. Over very long periods of time, surplus quantities of these are carried in run-off and deposited in wetlands, with serious adverse consequences. The common view that wetlands are purifiers of all pollution does not apply for some chemical pollutants.

In effect, this means that the campaign to make Kenya self-sufficient in food production may be continuing to degrade the country's wetlands to a point of no return. It is not my intention to cause alarm but to suggest the urgent need for a dialogue between Kenya's conservationists and agriculturalists to save the integrity of the country's wetlands.

There exists a need to set up a Kenyan Wetlands Group or Society, whose main responsibility should be to raise public awareness on policies which are threatening our wetlands and the steps needed to redeem the situation. The group could also recommend steps for rehabilitation of those wetlands which may have suffered damage and for stabilizing the flow of rivulets, small rivers and springs.

Proceedings of the KWWG Seminar on wetlands of Kenya, 3-5 July 1991

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Seminar sponsors

IUCN Wetlands Programme
IUCN Eastern Africa Regional Office

Seminar recommendations

On the afternoon of 5th July, the last session of the seminar, participants divided into four working groups to discuss possible recommendations from the seminar. The separate groups considered: wetlands policy for management, mechanisms for resolving wetland conflicts, topics for wetlands research and awareness, education and training in wetlands activities. The recommendations of the four groups were then presented and discussed in plenary session and some additional recommendations suggested. The following is an edited and resolved list of the seminar recommendations as agreed by the final meeting: the order is not of precedence and the first topics have been combined because of their common resolutions.

Policy and resolution of conflicts

1. Kenya should have a National Wetlands Policy.
2. Kenya should have an inter-ministerial government committee on wetlands that would represent all users and interest groups involved in wetlands.
3. There should be an Environmental Impact Assessment made of every development project that may affect wetlands; the EIA should be made public before the project is undertaken, and its recommendations should be incorporated in project planning and implementation.

4. The Seminar expresses particular concern about, and recommends urgent investigation into, the current status and future of:
   a) Lake Naivasha;
   b) the Lorian Swamp;
   c) the Yala Swamp;
   d) the Tana River Delta;
   e) Lake Turkana; and
   f) the other wetlands in the Arid and Semi-Arid Lands of Kenya.
5. More Kenyan wetlands should be included in the list of Wetlands of International Importance according to the Ramsar Convention.
6. Wetland action groups should be established (including the continuation of KWWG) and there should be more wetlands seminars.

Research in Kenyan wetlands

7. The Kenya Wetlands Working Group should move towards coordination of research and data gathering, and liaise with individuals and institutions in the field of wetlands research.
8. Wetland areas should be identified and a centralised, computerised inventory developed of Kenya's wetlands which sets criteria for their value as resources, as well as their value for sustainable utilisation and conservation.
9. There should be promotion of basic research on the taxonomy and ecology of wetland organisms which should lead to the production of manuals for recognition of wetland organisms to facilitate further research.
10. There should be socio-economic research and assessment of the traditional values and uses of wetlands, how the wetlands are perceived by traditional users and the possibilities for use of these findings in future planning and management of wetlands.
11. There should be systematic monitoring of key wetlands with respect to water flows, water quality and degradation effects as well as the populations of species that indicate ecological health.

Education and awareness

12. A resource centre should be established with facilities for reference and teaching on wetland issues.
13. Wetlands awareness should be included in school curricula, political education and media programmes and should be available to policy makers, the general public and specific (women's) groups.
14. Companies should be encouraged to sponsor media commercials with wetlands conservation and management messages.

General

15. The Seminar recognises and supports the recommendations on Marine and Coastal Wetlands made by the recent workshops on *Causes and Consequences of Sea Level Changes on the Western Indian Ocean Coasts and Islands, Towards Sustainable Coastal Tourism* and *The Ecology of Mangrove and Related Ecosystems.*
16. The Seminar recognises that the most important resource for the existence of wetlands is water itself and that the conflicting needs for this one commodity must always be considered in wetland discussions.

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