Sabkha Regions of Tropical East Africa

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Abstract Sabkhat in the region of tropical East Africa (treated here as Uganda, Kenya and Tanzania) are comparatively small in area and limited mostly to lake basins in the Eastern Rift and a few coastal areas. A relatively large inland sabkha lies in North Kenya, west of Lake Turkana, associated with the Chalbi Desert (a former lake). The chief plants of saline flats that surround the saline lakes in Kenya and Uganda include *Cyperus laevigatus*, *Sporobolus spicatus* and *Dactyloctenium* spp. The coastal sabkhat, flooded only at spring tides, are occupied by monospecific stands of stunted *Avicennia marina*. At the more open parts of the *Avicennia* fringe *Arthrocnemum indicum*, *Paspalum vaginatum*, *Sesuvium portulacastrum*, *Sporobolus virginicus*, *S. spicatus*, *S. kentrophyllus*, *Pedalium murex* and *Suaeda monoica* form the main associates. In the inland sabkhat low rainfall and high potential evaporation have resulted in an arid and saline landscape dominated by grasses *Aristida adscensionis*, *A. mutabilis*, *Drake-Brockmania somalensis*, *Sporobolus consimilis*, *S. virginicus and Psilolemma jaegeri*, and the subshrubs *Duosperma eremophilum* and *Indigofera spinosa*. *Lagenantha nogalensis* occurs on gypsophilous soils and *Dasysphaera prostrata* on saline soils at the edges of Lake Turkana and the Chalbi Desert. Stunted woody vegetation is dominated by *Acacia reficiens* and in drainage channels by *Salvadora persica*. Floristically the coastal sabkhat of tropical East Africa fall in the Zanzibar-Inhambane regional mosaic and the inland sabkhat in the Somalia-Masai regional centre of endemism. There are no endemic genera in the coastal sabkhat, but all of the nine East African mangrove species occur in Kenya, Tanzania and Mozambique. In the inland sabkhat, the Somalia-Masai regional centre of endemism includes the endemic genera *Drake-Brockmania* and *Dasysphaera*. There is no arid-zone agriculture in the inland sabkhat region and nomadic pastoralists, depending on their livestock for subsistence, are the main occupants; *Duosperma* and *Indigofera* are amongst some of the important food plants of livestock (camels). Salt deposits are harvested from the extensive flats surrounding the saline and soda lakes, and the mangrove is an important economic resource as a nursery for fish and crustaceans, as well as a source of poles, timber and firewood. Over-harvesting of wood and conversion to saltpans and aquaculture, housing and industry is a threat to many parts of the mangrove area. There are no strict nature reserves in the inland sabkhat of tropical East Africa designated for the protection of arid landscapes and its flora; however the Mount Kulal Biosphere Reserve in northern Kenya covers the salt desert and lake ecosystems; Lake Manyara and Amboseli Biosphere Reserves also partly cover the saline and alkaline ecosystems. Mangrove areas are included in Watamu Marine National Park, Kiunga National Marine Reserve and Ras Tenewi Marine National Park in Kenya, and in Mafia Island Marine Park, Jozani National Park and Sadaani Game Reserve in Tanzania. Other areas of East African mangrove are included in forest reserves, with varying degrees of protection.

1 Introduction

Sabkhat in the region of tropical East Africa (treated here as Uganda, Kenya and Tanzania) are comparatively

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small in area when compared to the extensive arid and saline areas of the Sahara desert and the Karoo-Namib region in southern Africa. In tropical East Africa sabkhat are limited mostly to lake basins in the Eastern Rift (mainly in the Kenyan Rift Valley) and a few coastal areas. A relatively large inland sabkha lies in north Kenya, west of Lake Turkana, associated with the Chalbi Desert (a former lake) (Fig. 1).

Lakes in the Eastern Rift were created by tectonic and volcanic activity associated with the formation of the Rift Valley (±2 myBP). Most of these are fed by springs and surface drainage and are thus rich in solutes; as most of these are closed lakes and water loss is only through evaporation, they are saline or alkaline and fluctuate seasonally in their solute concentration and water levels. Soda lakes in the eastern Rift valley are among the most biologically productive ecosystems in the world (Melack 1996) with phytoplankton and cyanobacteria attracting flocks of flamingos and other avifauna. The monospecific blooms of *Spirulina platensis* characteristic of soda lakes forms the primary graze for flamingos; it has also been a diet item for the people of Chad for many years (Léonard and Compère 1967)

The distribution of saline soils in East Africa is mainly determined by salt deposits in lake basins and valleys where the mean annual rainfall is between 250 and 1,000 mm. Some areas may not be sufficiently saline to have halophytic vegetation, such as the sodium soils created by rocks containing soda feldspar perthite, nevertheless they support a distinct vegetation. In this chapter we will describe the vegetation, the main plant communities and associated species, their local uses and economic importance, and conservation

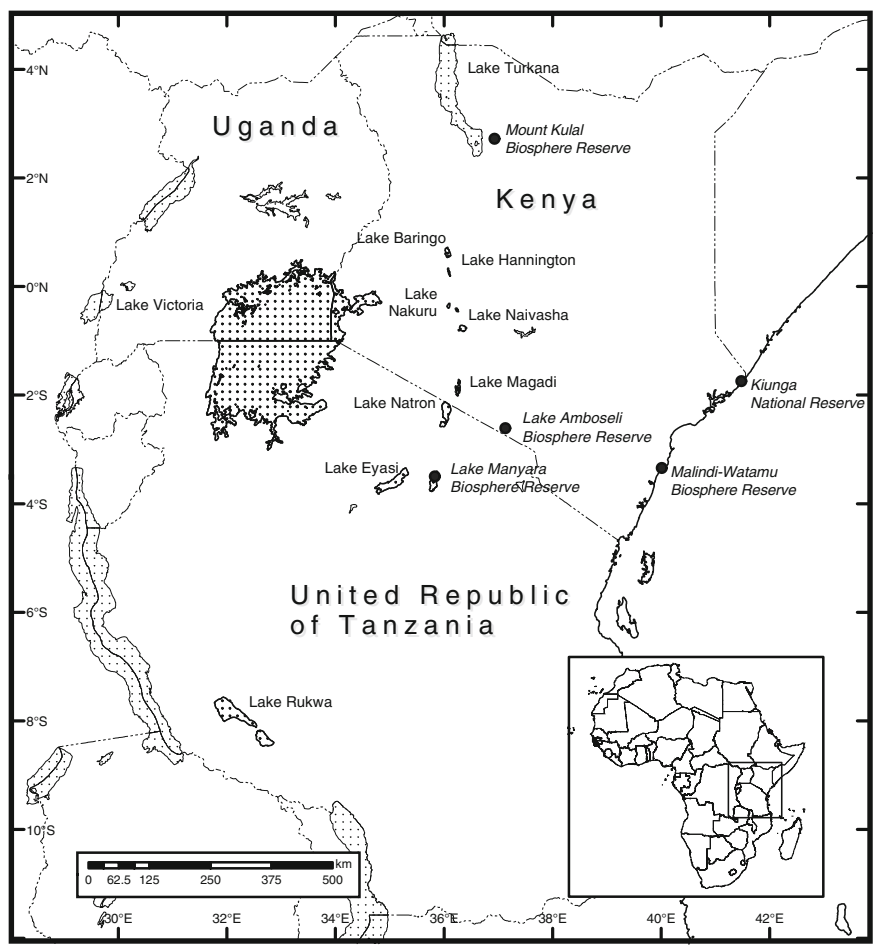

Fig. 1 Tropical East Africa, showing the location of the lakes and the Biosphere Reserves

status of coastal, true saline (soluble salts 0.2–0.3%) and alkaline (pH 8.0–9.6) ecosystems in tropical East Africa.

2 Inland Sabkhat

2.1 Saline Sabkhat

In tropical East Africa, the inland saline sabkhat are not extensive and occupy relatively small areas. A large area in northern Kenya in the Marsabit District, the Chalbi Desert and its immediate surrounding plains can be classified as an inland sabkhat.

The Chalbi desert is composed of saline and alkaline sediments and stabilised sand dunes associated with the old bed of Lake Chalbi. During the Pleistocene (1.8 mya to 10,000 years BP) this lake drained the volcanoes at Marsabit, but has since dried up to form the extensive Chalbi desert. The area lies in a depression between 430 and 500 m above sea level surrounding a large central plain. Precipitation is low with an average of between 100 and 250 mm a year for the region, occurring between March–May and October–December. Much of the drainage from the surrounding mountains (Mt Marsabit, Hurri Hills, Mt Kulal, Mt Nyiru, OI Doinyo Mara and Ndotos) is lost by evaporation and never reaches the Chalbi Desert.

2.2 Vegetation

The vegetation of the inland sabkhat in tropical East Africa (northern Kenya) falls under the Somalia-Masai regional centre of endemism which includes NE Uganda (Karamoja), most of Kenya in the North and between the Highlands and the coastal belt, and the dry lowlands of north and central Tanzania; the region is characterised by an *Acacia-Commiphora* deciduous bushland and thicket and secondary and wooded grassland. Two genera, *Drake-Brockmania* and *Dasysphaera* that are found in the inland sabkhat, are endemic to this floristic region.

The major part of the Chalbi desert itself is barren except for at the edges where there is subsurface water flow from springs from the surrounding mountains. Due to extensive evaporation the area is hyper-arid, and after seasonal rains and flood, the soil becomes highly saline supporting a few halophytic grasses. These too grow only near runnels and water outlets. In the surrounding plains and parts of the Chalbi Desert the most extensive vegetation type is the semi-desert annual grassland. Second to this is the semi-desert dwarf shrubland which occupies the stabilized sand dunes (White 1983). The main halophytic grass which grows in these locations is *Drake-Brockmania somalensis.* This is a mat-forming annual, spreading by stolons and rooting at nodes, and with leaves covered with stiff hairs. It occupies seasonally flooded places in silty and saline soils. *Drake-Brockmania somalensis* is distributed from Tanzania through to NE Africa (Sudan, Somalia, Ethiopia; excluding Uganda); it is also found on the Farasan Island (Saudi Arabia) in the Red Sea (Phillips 1997).

By far the most common and widespread in the desert and semi-desert are the annual grasses, *Aristida adscensionis* and *A. mutabilis.* They occupy the driest areas, extending up to elevations of 1,000 m on the drier parts of the surrounding hills. They occur on poor, shallow soils and during periods of drought may be absent for as long as the drought lasts (White 1983). Associated with these are a few species of subshrubs which form the perennial woody components of the sabkhat. Dominant amongst these are *Duosperma eremophilum* (Family Acanthaceae) and *Indigofera spinosa* (Family Leguminosae); the former found on relatively moister soils, and the latter on the drier soils. *Indigofera spinosa* is a small intricate subshrub found throughout the semi-desert grassland in East Africa and is distributed through Sudan, Somalia and Ethiopia to Arabia. It is also present in the dry *Acacia-Commiphora* deciduous bushland (Gillett et al. 1971). In northern Kenya, around settlements where there is heavy utilisation of vegetation through grazing and where soils are degraded, *Indigofera spinosa* is the main species. Its cover is 8.5% (Lusigi et al. 1986), and it forms the main graze for livestock.

Amongst other shrubs, *Lagenantha nogalensis* (Family Chenopodiaceae) a succulent that is tolerant of gypsophilous soils, forms almost pure stands on white calcareous soils of the old Chalbi Lake bed; *Dasysphaera prostrata* (Family Amaranthaceae) occurs on saline or alkaline soils at the margins of Lake Turkana and at the edges of the Chalbi Desert (White 1983).

There are a few annuals which come up after rain but are grazed out as soon as they appear. These form a very low cover (0–1%) and constitute only a few species such as *Cenchrus ciliaris*, *Dactyloctenium aegyptium*, *Psilolemma jaegeri*, *Sporobolus consimilis*, *S. virginicus*, *Gisekia pharnaceoides*, *Hermannia s*p. and *Limeum praetermissum*.

Only a few trees or large shrubs are associated with arid and saline soils. These are usually stunted, with *Acacia reficiens* as the dominant species; other species include *A. seyal*, *A. tortilis*, *A. horrida*, *A. senegal* and *Commiphora* spp. In areas degraded by intense grazing pressure the unpalatable *Calotropis procera* is widespread and *Salvadora persica* occurs on saline soils associated with the Chalbi drainage system.

2.3 Alkaline Sabkhat

The alkaline sabkhat are associated with lakes of the Rift Valley. Except for Lakes Baringo and Naivasha, the others on the Eastern Rift (Lake Bogoria, Nakuru, Elementeita, Magadi, Natron, Manyara, Eyasi and Rukwa) are highly alkaline and show salt deposits around their shores. Several are centres for the commercial harvesting of soda ash (Lind and Morrison 1974).

The main species around the saline lakes in Kenya and Uganda are *Cyperus laevigatus*, *Sporobolus spicatus* and *Dactyloctenium s*pp. The vegetation of the grassland on the flats close to Kiboko river is described by Bogdan (1958) which shows different dominant species inhabiting soils with different concentrations of salts: thus in slightly alkaline conditions the grass cover is mainly *Cenchrus ciliaris*, but as alkalinity increases *Chloris gayana* becomes dominant. With increasing moisture and alkalinity *Sporobolus consimilis* becomes the dominant species and where soils are shallow, *Cynodon dactylon* appears, and in highly alkaline soils that are waterlogged in the rainy season, *Sporobolus spicatus* takes over and forms dense growth. In the flat valleys in the drier parts of Tanzania, such as the Pangani River valley, where the waters are saline, the flood plains are dominated by grasses *Sporobolus consimilis*, and shrubs such as *Suaeda monoica*, *Sesbania sesban*, *Salvadora persica* and *Triplocephalum holstii*.

The vegetation of the Lake Rukwa basin in Tanzania, which is chiefly grassland has been described by Vesey-FitzGerald (1963); this is summarised here: the vegetation can be divided into three zones from the fringe of the lake to the lake bed itself. The edges of the lake are occupied by almost pure stands of *Sporobolus consimilis*. This species does not grow in water, but colonizes the alkaline soils on the beach of the lake. The shallowly flooded alkaline swamp present on the extensive flat lake bed is vegetated by the grass *Diplachne fusca*. This is a rhizomatous perennial rooting and branching from the lower nodes forming dense mats over large areas. *Diplachne fusca* is found throughout East Africa and is distributed right through the tropics and subtropics of the Old World including Australia (Clayton et al. 1974). On the lake bed, the alkaline flats are occupied by two species: when the lake is dry *Sporobolus spicatus* grows associated with *Psilolemma jaegeri*; when the flats are flooded with the highly alkaline water, *Psilolemma jaegeri* takes over and replaces *Sporobolus*.

Other saline and alkaline patches of vegetation exists around Lake Amboseli in Kenya, where the major vegetation type is the *Commiphora-Acacia* bushland, and the saline and alkaline plains are dominated by *Suaeda monoica* and *Salvadora persica*. Alkaline grassland dominated by *Sporobolus spicatus* is also present around Lake Manyara.

3 Coastal Sabkhat

The coastal plain consists of deposits of corals and sands with occasional dune formations (Lind and Morrison 1974). The climate is controlled by the monsoonal currents of the Indian Ocean, with long rains from April to June and short rains from October or November to January. Annual rainfall in the coastal strip decreases from ±1,425 mm in the South of Tanzania to ±1,075 mm in northern coastal Kenya. The mean annual temperature is 25°C and does not vary much (Dahdouh-Guebas et al. 2004).

Floristically the coastal sabkhat of tropical East Africa fall in the Zanzibar-Inhambane regional mosaic. There are no endemic genera in the coastal sabkha, but all of the nine East African mangrove species occur in Kenya and Tanzania: *Avicennia marina*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Heritiera littoralis*, *Lumnitzera racemosa*, *Pemphis acidula*, *Rhizophora mucronata*, *Sonneratia alba* and *Xylocarpus granatum* (Beentje and Bandeira 2007).

The mangrove is an important economic resource as a nursery for fish and crustaceans, as well as a source of poles, timber and firewood. Both mangrove trees and mangrove vegetation are decreasing in East Africa, particularly around urban areas and large villages. This is due to increasing populations and continuing poverty, leading to more tree cutting for fuelwood, building material and urban development; large mangrove areas are also converted into salt-pans or to agricultural land, and to a lesser extent for aquaculture purposes (oyster, shrimp and fish ponds). Coastal developments further threaten mangrove areas, and the main reasons are those of infrastructure and tourism; increased population has led to increasing pollution from industry and agriculture (e.g. crude oil, heavy metals, pesticides) (Semesi 1998).

3.1 Vegetation

Along the coast fringing coral reef is more or less continuous, and where it is lacking, mangroves occur. Much of the rocky coral shore is overlaid with sand (Lind and Morrison 1974). Mangrove forest is found in suitable sites all along the East African coast, from Egypt to South Africa, but in East Africa it reaches relatively high diversity, with the mouth of the Rufiji River in Tanzania among the richest mangroves in Africa.

The true mangrove is flooded regularly, but an area inland of the mangrove is flooded only twice a year (during the equinoctal spring tides), and the salt content of the sandy soil is so high through evaporation that often vegetation is almost absent. During the rainy season the salt is leached out, and so even halophytes have to struggle to cope with this changing habitat. The vegetation cover is usually low, in the region of 10% on the edge of the mangrove, just about the High Water Mark (HWM), to virtually absent in the area only flooded by the spring tides (Walter and Steiner 1936; Knapp 1973; White 1983; Table 1).

Diversity is low, with twelve species reported (see the list below). *Avicennia marina* and *Lumnitzera racemosa* both are mangrove trees, but extend into the sabkha zone, becoming more stunted as the salt concentration in the soil increases. *Avicennia* extends into the sabkha zone thanks to its capacity to withstand high salt concentrations; McCusker (1977) reports that the upper limit of soil osmotic potential for other East African mangrove trees is between 38.8 and 50.1 atm, but that of *Avicennia* is up to 97.8 atm. The pneumatophores of *Avicennia* are colonized by red algae *(Bostrychia* sp.). *Suaeda monoica* may form large stands on the edge of the barren sand flats, while *Arthrocnemum indicum*, *Sporobolus virginicus* and *Suaeda monoica* grow on slightly elevated soil between the HWM and the barren zone. *Salicornia pachystachya* may form carpets in summer.

Table 1 List of coastal salt marsh halophytes (Data from Walter and Steiner 1936; Knapp 1973; White 1983)

Chenopodiaceae	Between the stunted Avicennia zone and the vegetation-free sandflats, about the HWM
Suaeda monoica J.F.Gmel	
Arthrocnemum indicum (Willd.) Moq.	On slightly raised parts just above HWM
Salicornia pachystachya Ungern.-Sternb.	On slightly raised parts just above HWM
Gramineae	
Sporobolus spicatus (Vahl) Kunth	No detail
Sporobolus kentrophyllus (K.Schum.) W.D.Clayton	On slightly raised parts just above HWM
Sporobolus virginicus (L.) Kunth	No detail
Paspalum vaginatum Sw.	No detail
Dactyloctenium geminatum Hack.	No detail
Pedaliaceae	
Pedalium murex L.	No detail
Aizoaceae	
Sesuvium portulacastrum (L.)L.	About HWM, in moister sites
Verbenaceae/(Avincenniaceae)	
Avicennia marina (Forssk.)Vierh.	Next to mangrove,the more inland ones becoming more stunted
Combretaceae	
Lumnitzera racemosa Willd.	Next to mangrove in slightly moister sites, the more inland ones becoming more stunted

4 Utilisation and Economic Importance

There is no arid-zone agriculture in the inland sabkhat of tropical East Africa. Nomadic pastoralists are the main occupants in this area, and the region is used as a basic grazing resource for their livestock (camels, cattle and goats). *Duosperma* and *Indigofera* are amongst some of the important food plants, and wood from the larger shrubs is used as a source of fuelwood and materials for livestock fencing. The Range Resource Assessment and Management Strategies for South-Western Marsabit, Northern Kenya (Lusigi et al. 1986) showed that the rangelands were heavily utilised, well beyond their carrying capacity leaving the soil barren and encouraging erosion. The annuals provide little cover, but are grazed very soon after they come up.

Harvesting of salt from the saline and soda lakes is an important industry in tropical East Africa. In western Uganda, Lake Katwe, a closed crater lake fed by brine springs is an important source of salt and revenue. Soda ash, harvested from Lake Magadi in Kenya is also of much economic importance to the country.

Uses of plants of coastal regions are minimal, apart from some casual grazing or fodder collecting (reported for *Avicennia marina*) and use as vegetables (reported for *Pedalium murex*, *Sesuvium portulacastrum*); plus some firewood collection. Hence, economic importance is virtually nil.

5 Conservation and Designated Protected Areas

There are no strict designated protected areas in the inland sabkhat of tropical east Africa for the protection of the flora per se. However several Biosphere Reserves are designated as part of the UNESCO Man and the Biosphere Programme which are essentially aimed at the conservation and sustainable development of terrestrial and coastal ecosystems and are recognised within the framework of UNESCO (Clüsener-Godt 2002). Amongst these is The Mount Kulal Biosphere Reserve in northern Kenya, established in 1978 and situated on the eastern side and southern end of Lake Turkana, with Mount Kulal in its centre. The area comprises a variety of landscapes and habitats, including brackish water at the southern end of the Lake, a volcanic landscape with lava flows, an extensive lava desert and a volcanic island within the lake, hot springs, the occasionally flooded Chalbi salt desert, sand dunes and seasonal water courses. The Amboseli Biosphere Reserve located in the south of Kenya and the Lake Manyara Biosphere Reserve in Tanzania offers protection to the saline and alkaline ecosystems (Fig. 1) (UNESCO 1977; UNEP-WCMC and the IUCN World Commission on Protected Areas (WCPA)).

There is increasing anthropogenic pressure on the coastal sabkhat ecosystems in East Africa. Fuelwood exploitation, urban development, tourism development, and conversion to saltpans and aquaculture are on the increase. Pollution from an increasing population and industry also contribute to the threats; for an overview of the various factors (see Semesi 1998). In Kenya, around 70% of the people living on the coast rely on mangrove poles for construction (Beentje and Bandeira 2007) and so access to the mangroves, which necessarily goes through the sabkha, would result in trampling and compaction.

Mangrove areas, including coastal sabkha areas, are included in Watamu Marine National Park, Kiunga National Marine Reserve and Ras Tenewi Marine National Park in Kenya, and on Mafia Island Marine Park, Jozani National Park and Sadaani Game Reserve in Tanzania. The Malindi-Watumu Biosphere Reserve (IUCN Management Category II, VI, IX: National Park, Resource Reserve, Biosphere Reserve) located south of Malindi was established in 1981. This includes intertidal rocks, sand and mud flats and sublittoral areas; the Mida Creek mud flats with fringing mangrove swamps with *Rhizophora mucronata, Bruguiera gymnorrhiza* and *Ceriops spp.* are also included. It also offers protection to the nesting grounds for the roseate tern, *Sterna dougalii* and the bridled tern, *S. anaethetus.* Several species of shore birds and crabs, and sea grasses *Thallasia chemprechii, Syringodium s*pp., *Cymodocea* spp., and *Halodule wrightii* on the intertidal sand and mud are also included in the Reserve (UNEP WCMC, Protected Areas Programme). Other areas of East African mangrove are included in forest reserves, with varying degrees of protection.

6 Conclusions

The sabkhat regions of tropical East Africa are few and limited in overall area, nevertheless constitute an important ecosystem that provides habitats for a number of plants and animal species, and contributes to the economy of the region. As most arid regions in Africa, the sabkhat are also over-utilized and are in need of management and protection. This is especially relevant for the coastal sabkhat, which are constantly subject to damage due to coastal development and over-use of coastal resources. The conservation and the sustainable use of coastal sabkhat should be a priority for any conservation and management plan for a country with setting up more Biosphere Reserves essential for the protection and proper management of coastal regions. Programmes on establishing living halophytic collections and genetic material for restoration, and undertaking research projects to understand the dynamics of coastal and inland sabkhat ecosystems are also necessary to preserve these important ecosystems.

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