Plant Ecology and Evolution 144 (2): 126–137, 2011
doi:10.5091/plecevo.2011.539

REGULAR PAPER

Coastal dry forests in northern Mozambique

Jonathan Timberlake[1,*], David Goyder[1], Frances Crawford[1], John Burrows[2], G. Philip Clarke[3], Quentin Luke[4,5], Hermenegildo Matimele[6], Tom Müller[7], Olivier Pascal[8], Camila de Sousa[6] & Tereza Alves[6]

[1]Herbarium, Royal Botanic Gardens Kew, Richmond, Surrey UK-TW9 3AB, United Kingdom
[2]Buffelskloof Herbarium, P.O. Box 710, Lydenburg 1120, South Africa
[3]The Hermitage, Crewkerne, Somerset UK-TA18 8HA, United Kingdom
[4]East African Herbarium, National Museums of Kenya, P.O. Box 45166, 00100 Nairobi, Kenya
[5]Centre for Tropical Plant Conservation, Fairchild Botanic Garden, 11935 Old Cutler Road, Coral Gables, FL 33156-4242, USA
[6]Herbarium, Instituto de Investigação Agrária de Moçambique, C.P. 3658, Maputo, Mozambique
[7]5 Vollendam, 13 J. Tongogara, Harare, Zimbabwe
[8]Pro-Natura International, 15 Avenue de Ségur, Paris FR-75007, France
*Author for correspondence: j.timberlake@kew.org

Background and aims – The Coastal Forests of Eastern Africa, stretching along the Indian Ocean coastline from Somalia to Mozambique, are considered by Conservation International to be a global biodiversity hotspot – an area of high diversity and endemism under increasing threat. Although the largest remaining extent of these forests is reported to be found in Mozambique, very little is known on their extent, condition and composition here. In addition, the term 'coastal forest' has been used in different ways by different authors. This paper defines and characterises coastal dry forests found in northern Mozambique and assesses their present extent, botanical composition, conservation importance and the threats to these forests.
Methods – The study area of 18,150 km^2 lies in Cabo Delgado Province in north-east Mozambique, adjacent to Tanzania. Its limits are determined primarily by geological substrate and landform. Four smaller study sites were chosen covering a range of landforms. Manual interpretation of satellite imagery dating from 1999–2002 was used to calculate possible previous and present extent of 'dense vegetation'. Extensive field collecting was used in determining botanical composition and distribution patterns. IUCN Red List assessments were carried out on selected species using distributional criteria.
Results – Dry forests similar to those in southern Tanzania are found widely scattered across coastal Cabo Delgado, sitting in a matrix of miombo woodland and other vegetation types. However, forest cover is not as extensive was believed. We calculate that the original extent of 'dense vegetation cover', which includes coastal dry forest, was 6087 km^2. Owing to clearance over the last 150 years this is now only 1182 km^2, of which perhaps only 400 km^2 is moderately-intact dry forest.
In this southern part of their range such forests are essentially dry, not moist and mesic, and dominated by a high proportion of deciduous or sclerophyllous evergreen trees. The plant species composition differs significantly from that of the surrounding woodlands. There is a marked change in species composition between forest patches along the coast, and they contain numerous species with restricted global distribution. Since 2003, 68 species new to Mozambique have been recorded from Cabo Delgado in addition to 36 possible new species. Many new records are of species previously only known from south-eastern Tanzania. Previously recorded patterns of restricted distribution and high species turnover between forest patches in Kenya and Tanzania are confirmed. Seven coastal forest species were assessed as Endangered.
Regional context and conservation – Coastal dry forests are discussed in relation to the more widespread 'sand forests' of the continental interior of south-central Africa, and shown to have similarities in ecology, species composition, soils and ecology. Very little of the present extent of coastal forests in Mozambique lies within protected areas. The threats to their continued existence in the face of exploitation for timber, agriculture and oil exploration are outlined.

Key words – Mozambique, coastal forest, endemics, hotspot, conservation.

INTRODUCTION

The Coastal Forests of Eastern Africa are considered by Conservation International (CI), an international conservation organisation, to be a global biodiversity hotspot – an area of high species diversity and endemism that is under increasing threat (Myers et al. 1999, Burgess et al. 2004b). The same area along the eastern African coastline has also been recognised by the World Wide Fund for Nature (WWF) as a globally important ecoregion – the Eastern Africa Coastal Forest Ecoregion (Burgess et al. 2004a) – with a specific programme directed towards its conservation (WWF-EARPO 2006). This hotspot or ecoregion extends from southern Somalia through Kenya and Tanzania to southern Mozambique (fig. 1), although most of our knowledge on the area comes from studies in Kenya and Tanzania (e.g. Moomaw 1960, Greenway 1973, Brenan 1978, Robertson & Luke 1993, Hawthorne 1993, Vollesen 1994, Burgess & Clarke 2000, Burgess et al. 2004a).

It has often been assumed that the major extent of remaining intact vegetation in this hotspot lay in northern Mozambique in the provinces of Cabo Delgado and Nampula (Burgess et al. 2000, Burgess et al. 2004a, WWF-EARPO 2006), but to date there has been little direct evidence of this in terms of mapped forest extent. Historical plant collections from the 1940s to mid-1960s suggested that some restricted-range species, otherwise only known from coastal southern Tanzania, were also found here (Brenan 1978, Clarke et al. 2000: 137) along with some Mozambique endemics, but the extent of forest remaining and the significant presence of range-restricted or endemic species was speculative.

Following the instability resulting from the independence and civil wars, development is now occurring at a rapid rate in the country, including exploration for onshore oil and gas, and this is likely to accelerate the loss of what remains of these coastal forests. The investigation of coastal northern Mozambique is an obvious priority for botanists and conservationists.

Coastal Mozambique falls within what White (1983) terms the Zanzibar–Inhambane regional mosaic, a phytochorion stretching along the East African coast from Somalia down to South Africa. This area has a distinctive flora, different from that found further inland in the Zambezian regional centre of endemism. Unfortunately, White did not map any of the coastal dry forest patches within this rather broad regional mosaic, and his descriptions of dry forest vegetation is skewed towards that found in Kenya. Within the mosaic he describes ten vegetation types of which four (Zanzibar–Inhambane undifferentiated forest, Zanzibar–Inhambane transition woodland, Zanzibar–Inhambane woodland and scrub woodland and Zanzibar–Inhambane secondary grassland and wooded grassland) seem to occur in north-east Mozambique. Much of the Cabo Delgado study area falls within what White calls Zanzibar–Inhambane woodland and scrub woodland. Surprisingly, he does not explicitly recognise dry coastal forest as a separate type in Mozambique, unlike Wild & Barbosa (1967) on which much of White's work for the country was based.

More recently, on the basis of species richness and composition, Clarke (1998) has split White's Zanzibar–Inhambane regional mosaic into two separate phytochoria – the Swahilian regional centre of endemism in the north and the Swahilian/Maputaland regional transition zone in the south.

Figure 1 – Area with coastal forests in Eastern Africa (adapted from Burgess et al. 2004b).

The only vegetation maps available for this part of northern Mozambique are those by Pedro & Barbosa (1955) and the Flora Zambesiaca vegetation map (Wild & Barbosa 1967), which was partly based on the former. Both maps show that Cabo Delgado has a somewhat different vegetation from other parts of Mozambique, and that most of it is covered in a type of miombo woodland. However, these maps show areas of Dry Deciduous Lowland Forest on the Mueda plateau, a vegetation type that appears to have largely disappeared, and, of particular interest to us, Dry Deciduous Thicket with *Guibourtia schliebenii* (Harms) J.Léonard, the type that formed part of the main focus of the present study.

In recent years there has been renewed interest in coastal Mozambique. In 2003, Quentin Luke, who had previously studied the moister coastal forests of Kenya and northern Tanzania, visited Cabo Delgado on behalf of WWF and CI and collected a number of new plant records (Luke 2006), followed by John and Sandie Burrows in 2005–2008 in the course of writing a tree field guide for Mozambique. Results from these collections are incorporated here. In 2008, the French NGO Pro-Natura International, together with the Muséum National d'Histoire Naturelle in Paris, obtained funding to carry out preliminary biological surveys of plants and various vertebrate and invertebrate groups in this hotspot in Cabo Delgado Province, resulting in two major expeditions in 2008 and 2009. Other institutional partners in the study were the Instituto de Investigação Agrária de Moçambique, the herbarium of the Royal Botanic Gardens, Kew and the Buffelskloof Herbarium in Lydenburg, South Africa.

This paper outlines initial findings on the extent and botanical composition of forests in Cabo Delgado Province arising from these recent expeditions and studies, and discusses their links to similar dry forests elsewhere in Eastern and Southern Africa.

WHAT ARE COASTAL FORESTS?

The term 'coastal forest' has been used widely in recent years (e.g. Hawthorne 1993, Robertson & Luke 1993, Myers et al. 1999, Burgess et al. 2004a, Burgess & Clarke 2000, Clarke 2000a, WWF-EARPO 2006) but there has been inconsistency in definition. In some cases, most of the dense vegetation formations found in the coastal area (e.g. within 100–150 km of the coast) or within White's (1983) Zanzibar–Inhambane phytochorion are included, whilst others (e.g. WWF-EARPO 2006) have included various forest or woodland formations (except mangroves) up to 300 km inland, possibly as they were lowland vegetation types or contained some species with a typically East African coastal distribution. But unless such coastal species are dominant they can not realistically be termed coastal forests.

Clarke (2000a) formally defines East African Coastal Forests as forests (i.e. a continuous stand of trees with crowns overlapping or interdigitating, usually comprising several layers and/or interlaced with lianas, often with a sparse or absent ground layer) dominated by Swahilian endemic or near-endemic tree species, and describes six different types. The term is used collectively to encompass both typical Eastern African coastal dry forests as well as variant and transitional formations where they share features with forests of other phytochoria. On the other hand, Hawthorne (1993) adopts a more geological and geomorpohological definition, defining 'coastal' as lying on sedimentary (or volcanic) sediments of the coastal plains and plateaux, excluding any vegetation formations on Basement Complex substrates.

However, in practice areas termed 'coastal forest' shown on some recent maps have covered a wide range of vegetation from dense woodland through dry forest to true moist forest. More importantly, in some cases there appears to be no common or linking feature between these 'forest patches' in terms of species composition or ecology, which has led to confusion in determining the distribution of coastal dry forests in Mozambique, their biodiversity attributes, ecology, possible origins and conservation significance. The assumed commonality in terms of the origin and conservation importance of this group of vegetation types has masked our understanding of them, and perhaps inhibited selection of important or representative areas for conservation.

In this study we have attempted to define 'coastal forest' in a more restricted way, at least as regards those in northern Mozambique. It is hoped this definition and understanding will apply equally well to forests in Tanzania south of the Rufiji River.

We define coastal dry forest here as essentially dry forest or thicket formations that are found within 50–100 km of the coast. These are generally vegetation formations with a closed or almost-closed canopy (80% cover or more when undisturbed) with a high proportion of deciduous woody species that lose most of their leaves during the long dry season. The definition does not include moist forest, i.e. forest dominated by species with non-drought adapted leaves, nor does it include vegetation that is dominated or characterised by what are primarily woodland species (such as *Brachystegia* or *Julbernardia*). Moist forests of the continental interior may contain some tree species that are found in coastal forests, but, unless such species are dominant, this does not mean they are coastal forests. These moist forests, miombo and similar woodlands and mangroves are excluded, as is vegetation associated with watercourses such as rivers. Coastal dry forests are characterised as much by their species composition as by their physical structure (which can of course be modified by land uses such as logging or cultivation). Under our definition the main characteristics of coastal dry forests are:

- Dry, deciduous and semi-deciduous forest (80% canopy cover or more), becoming thicket-like with disturbance. The main species are not moisture-demanding or even mesic. They occur in areas subject to a lengthy dry season (in excess of 6 months), with the majority of tree species responding by losing leaves.
- Contain a significant number of sclerophyllous evergreen tree and shrub species in the understorey.
- Have a species composition significantly different from that of the surrounding woodland (mostly miombo). The overlap in species composition between the two types is often less than 30%.
- Have a very patchy distribution, and are often apparently restricted to particular soils, such as unconsolidated sands, and geomorphological positions, such as in the upper part of the catena.
- Show a marked change in species composition between patches with very few species found regularly or widely. There are a high number of species of restricted distribution, often from particular families and genera (e.g. Annonaceae, Leguminosae: Caesalpinioideae, Rubiaceae).

Typical sclerophyllous species commonly found in coastal forests across Cabo Delgado include *Manilkara sansibarensis* (Engl.) Dubard, *Warneckea sansibarica* (Taub.) Jacq.-Fél. and *Baphia macrocalyx* Harms, while *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels and *M. sansibarensis* are among the very few that are found in most forest patches.

STUDY AREA

The study area runs the length of Cabo Delgado Province in north-eastern Mozambique from the Rovuma river, the border with Tanzania, south to Pemba, with an extent of 18,150 km^2 (fig. 2). Forming a long triangle, about 280 km at its longest and 100 km at its widest, between Mueda and Mocímboa do Rovuma in the west, Quionga and the Rovuma estuary in the northeast, and Pemba in the south, its limits are based on geology and landform, encompassing only Cretaceous and more recent deposits. Full details are given in Timberlake et al. (2010).

Four smaller study sites were chosen (fig. 2) on the basis of their apparent good condition and size, uniqueness and accessibility, and as they were different from each other in terms of landscape and substrate.

a) Pundanhar–Nangade in Palma and Nangade Districts, west of the Nhica area along the W-E higher ground associated with the Rio Rovuma, including a hunting concession (approx. 750 km^2).
b) Palma–Nhica do Rovuma area in Palma District, along the W-E higher ground associated with the lower reaches of the Rio Rovuma and along the main road south from

Palma (approx. 1400 km²).

c) Quiterajo in Macomia District, situated on the coast 45 km south of Mocímboa da Praia, just south of the Rio Messalo (approx. 750 km²).

d) Lupangua in Quissanga District inside the Quirimbas National Park, 15 km south of Quissanga and opposite Ilha Mefunvo (approx. 25 km²).

Our principal focus was on coastal dry forest formations, so associated vegetation types such as *Brachystegia*-dominated miombo and similar woodlands, pan grassland and riverine formations, were only looked at in order to obtain a broader context.

Geomorphology, geology and soils

The area comprises a gently tilting interior plateau, rising from about 100 m above sea-level along the Palma–Mocímboa road to over 600 m in the west along the Mueda escarpment. However, most of our study sites lie between 80 and 180 m, although patches of dry forest were found down to an altitude of 40 m. To the east of the Palma–Mocímboa road the land drops down to a narrow coastal plain. Much of the interior plateau acts as a 'sponge' with pans and edaphic grasslands resulting from seasonally-poor drainage. There are numerous drainage lines flowing to the south east or, in the northernmost section, to the north east, and some are quite deeply incised closer to the coast. On the northern margin, the Rio Rovuma has cut through these plateau sediments to create a wide valley (c. 10 km wide), forming the border with Tanzania. Similar land forms are found in south-east Tanzania.

North-eastern Cabo Delgado is seen to have a different geological origin from much of the rest of Mozambique (national geological map, ING 1987), comprising younger formations dating from the Lower Cretaceous period up to the Neogene lying adjacent to the much older continental block of Precambrian granites and other rocks. There is also a narrow coastal strip comprising uplifted recent Quaternary deposits. As strata in these apparently marine deposits are relatively level, the landform is primarily determined by differential resistance to erosion by the different strata and retreating scarp erosion, resulting in numerous flat-topped plateaux.

Nearly all the coastal dry forest patches seen were located on iron-rich sandstone and conglomerates of the Mikindani Formation (mid-Neogene, ± 15–10 mya), while associated miombo and similar woodlands were found on more recent Quaternary formations (Pleistocene, ± 1.6–0.01 mya). This is clearly seen in the Quiterajo area with its forest-capped plateau, but is less obvious along the Rovuma rim (Nhica do Rovuma to Nangade).

It would appear that the extent of soils derived from the Mikindani Formation, comprising coarse, unstructured, well-drained sands, red-brown in colour, and possibly quite acidic, are a major determinant of the distribution of coastal forests here. However, this link has not yet been tested and causation is not fully established.

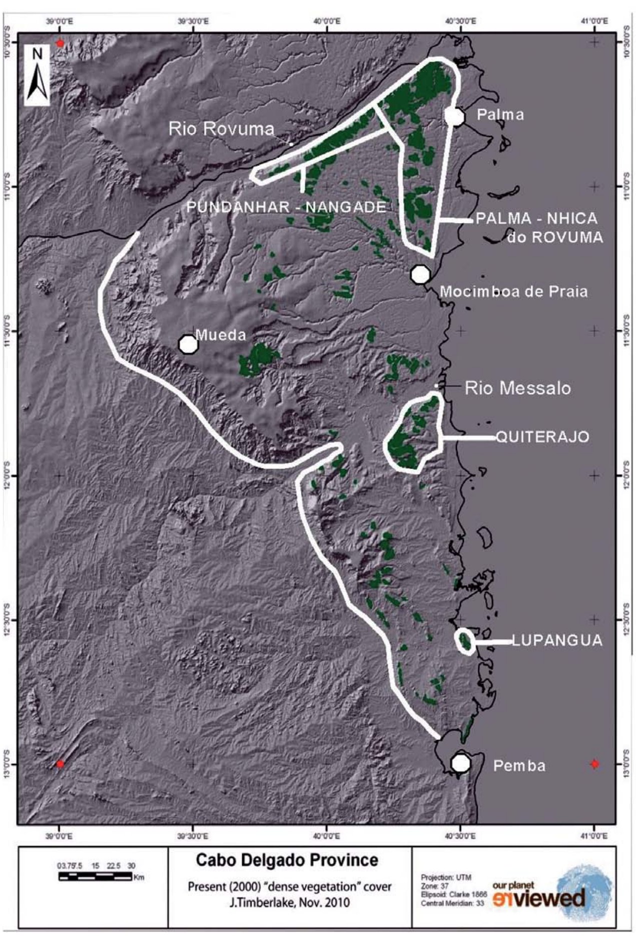


Figure 2 – Cabo Delgado study area showing the four detailed study sites (white lines), and present extent of 'dense vegetation' cover (green blocks).

Climate

Summary monthly data have been taken from Kassam et al. (1981), which covers various nearby localities. Rainfall is around 1000 mm/year falling in a single rainy season, while potential evapo-transpiration significantly exceeds rainfall for the period May to November–December, giving a growing season of around 4–5 months. There is a long hot dry season before a single clearly-defined rainy season from December to April, while atmospheric humidity during November and early December is high.

Although there is a coastal influence and some effects from the Indian Ocean monsoon, the climate of the study area generally follows that more typical of the continental interior. This part of northern Mozambique lies partly in the rain-shadow of Madagascar (Clarke 2000b), so has a somewhat lower rainfall than areas of the country further south or central Tanzania.

SURVEY RESULTS

Past and present extent of forest

Estimates of the remaining extent of coastal dry forest and similar formations in the study area were made using photographic copies of 1999–2002 false-colour Landsat ETM imagery at 1 : 250,000 scale. An approximation was also made of the possible original extent of dense vegetation cover some

Table 1 – Original and remaining extent of dense woodland and dry forest vegetation types, based on interpretation of 2002 Landsat imagery.

area	original extent (km²)	present extent (km²)		loss of dense veg. cover (%)
		dense veg. cover	dry forest	
NW, Mueda plateau & E slopes	2332	89	30	96.2
NE, Nangade–Pundanhar–Nhica–Quionga–Palma–Mocímboa	2173	769	260	64.6
EC, Rio Messalo–Quiterajo	576	166	55	71.2
S, Chai–Mucojo–Pemba, S of Rio Messalo	1006	158	53	84.3
total	6087	1182	398	80.6

100–150 years ago, before significant changes in land use occurred. Delineation was by manual interpretation using a transparent mylar sheet overlay; a dot planimeter was used to determine area. Results are presented by geographical block.

Original extent – The possible original extent of dry forest was determined using a combination of (a) suitable upland landform, (b) underlying geology, and (c) reflectance (smooth, reddish texture on false-colour imagery). A reduced image at 1: 800,000 scale was used to obtain a better synoptic view. Based on field observations of current species composition and distribution, as dry forest patches appear to be restricted to certain soils and landscape units, it is believed that only 10% of the area delineated as 'dense vegetation cover' would have been dry forest, with the majority being miombo or similar woodland types. However, these figures may be significantly in error.

The suggested original extent of 'dense vegetation cover' was 6080 km² (table 1), and within that the extent of dry forest is estimated at around 615 km², or 3% of the entire study area. Even with a higher proportion of dry forest vs. woodland, the original extent is unlikely to have been more than 1000 km². Although the assumptions are not substantiated, given the lack of historical data this is probably the best figure that can be obtained. The main densely vegetated areas were thought to be in the north along the Rovuma margin and along the eastern slopes of the Mueda plateau, but there were also significant blocks around the lower reaches of the Rio Messalo and in the Macomia area.

Present extent – A more detailed assessment using 1 : 250,000 scale images was made of the present extent of dense vegetation cover. Various key assumptions were made, including (a) that relatively smooth-textured non-mottled reddish areas on false-colour imagery indicate well vegetated sandy soils from the Mikindani Formation, most of which lie up on the plateau, while blue areas indicate woodland or grassland; (b) that deeper red-hued, ± homogeneous blocks are likely to be dry forest or dense woodland; (c) mottled areas include significant cultivation and were excluded; (d) around a third (rounded figures) of suitable substrate is likely to support dry forest patches rather than dense woodland, transitional areas or areas with just a sprinkling of dry forest species; and (e) rugged terrain along the Rovuma valley rim was included as field experience showed these areas support some good dry forest patches.

Based on these assumptions, the total extent of 'dense vegetative cover' was calculated to be 1182 km² in 2002, with 398 km² of this being dry forest (table 1), or 2% of the total study area. The overall loss of dense vegetation cover from the entire study area over the last 100–150 years appears to be around 80%, with losses ranging from 96% on the Mueda plateau to around 65% in the Nhica area.

The main dry forest areas are now found in the north-east part of the study area associated with the southern margin of the Rovuma valley from Pundanhar to Nhica do Rovuma, and in the Quionga area associated with the Rio Luvumba/Macanga that flow into the Rovuma estuary (fig. 2). There are also sizeable areas along the Palma–Mocímboa da Praia road. Other significant areas of dry forest include Nahavara forest near Quiterajo (31 km²) and others south of this, and the patch at Lupangua (20 km²) in the Quirimbas National Park.

It is clear that large parts of the area have been cleared for agriculture over the last 100 years, yet our field work suggests significant additional expanses have been cleared close to population centres and main roads since 2002. It is also thought that forest quality on the ground is often low owing to previous logging, old clearance for fields (5–50 years ago), and frequent fire, none of which are readily detectable on the imagery. Hence the figure of almost 400 km² of remaining dry forest extent given here is likely to be an overestimate from a conservation viewpoint.

Botanical composition

The main focus of the botanical study was on plant collection, particularly from the dry forest patches. More open vegetation types, such as around pans, on the coastal margins and in the Rovuma valley, were not well-collected. The expeditions took place just before the rains, so grasses and herbs are poorly represented. Representative sets are held at RBG Kew (K), IIAM in Maputo (LMA), and at the Muséum National d`Histoire Naturelle, Paris (P), with any additional duplicates in Maputo (LMU), Nairobi (EA) and Buffelskloof (BRNH). Earlier identifications were done by Quentin Luke (EA) and John Burrows (BRNH), with all others and confirmation done at Kew, primarily by David Goyder, Frances Crawford and Iain Darbyshire.

Over 3000 numbered collections were made during the various earlier trips and two expeditions in 2008 and 2009. A total of 738 plant taxa were recorded from 105 families, of which 36 taxa are either entirely new to science or were known previously from material too fragmentary to describe formally (table 2; see Burrows 2009, Burrows & Burrows 2010). The largest family recorded was Rubiaceae with 83

Table 2 – New and undescribed species recorded from Cabo Delgado study area, 2003–2009.

Monocotyledons
Asparagaceae
Asparagus ?sp. nov.
Araceae
Stylochaeton sp., uncertain status
Dicotyledons
Annonaceae
Xylopia sp. nov.
Xylopia sp. A of FTEA
Asteraceae
Vernonia ?sp. nov. aff. *inhacensis* G.V.Pope
Vernonia ?sp. nov. 2
Celastraceae
Pleurostylia ?sp. nov. aff. *serrulata* Loes.
Convolvulaceae
Ipomoea ?sp. nov.
Euphorbiaceae
Euphorbia ?sp. nov. aff. *ambroseae* L.C.Leach
Flacourtiaceae
Casearia ?sp. nov.
Lamiaceae
Vitex ?sp. nov. aff. *buchananii*
Vitex cf. *mossambicensis* Gürke
Leguminosae: Mimosoideae
Acacia latispina J.M.& S.M.Burrows
Leguminosae: Papilionoideae
Baphia ?sp. nov.
Erythrina ?sp. nov.
Melastomataceae
Warneckea sp. nov.
Meliaceae
Trichilia ?sp. nov.
Ochnaceae
Ochna ?sp. nov.
Rubiaceae
?*Chassalia* cf. *umbraticola* Vatke
Didymosalpinx callianthus J.E.& S.M.Burrows
Oxyanthus sp. A of FZ
Oxyanthus biflorus J.E.& S.M.Burrows
Polysphaeria ?sp. nov.
Psilanthus sp. nov., cf. sp. A of FTEA
Pyrostria sp. B of FZ
Pyrostria sp. D of FTEA
Pyrostria ?sp. nov. = Luke 9724
Rytigynia cf. *umbellulata* (Hiern) Robyns = de Koning et al. 9759 of FZ
Tarenna sp. 53 of Degreef 2006
Tricalysia sp. A of FZ
Tricalysia sp. B of FZ
Rutaceae
Vepris sp. nov.
Zanthoxylum lepreurii Guill.& Perr., subsp. nov.?
Sapindaceae
Deinbollia ?sp. nov.
Sterculiaceae
Cola sp. nov. 1 aff. *clavata* Mast.
Cola ?sp. nov. 2 aff. *clavata* Mast.

taxa, followed by Leguminosae: Papilionoideae with 43 (table 3). The family with the largest number of new species was Rubiaceae (thirteen), followed by Annonaceae, Asteraceae, Lamiaceae, Papilionoideae, Rutaceae and Sterculiaceae with two each. A full list of species identified is given in Annex 2 of Timberlake et al. (2010). Excluding new species, 68 new records are reported for Mozambique (table 4) from the study area and immediate surrounds. We believe that this is an exceptionally high number of new records to discover anywhere in southern and eastern Africa, and indicates not just the marked lack of previous collecting, but also the richness of the area and the high number of range-restricted species.

Distribution patterns

One of the study's objectives was to see if the patterns of local endemism recorded from the Tanzania coast, especially in the Lindi region (Bidgood & Vollesen 1992, Vollesen 1994, Clarke 1998, 2001), were also seen in coastal northern Mozambique. This would require the mapping of distributions of a large number of species using records both from this study and from herbaria elsewhere, and has not yet been done. Instead, some preliminary observations are given on broad species distribution patterns for seven selected species and on differences between vegetation types.

All available records for these seven species, known to be restricted to coastal areas and showing differing distribution patterns, were collated and mapped (fig. 3). Two species are endemic to coastal northern Mozambique [*Micklethwaitia carvalhoi* (Harms) G.P.Lewis & Schrire and *Thespesia mos-*

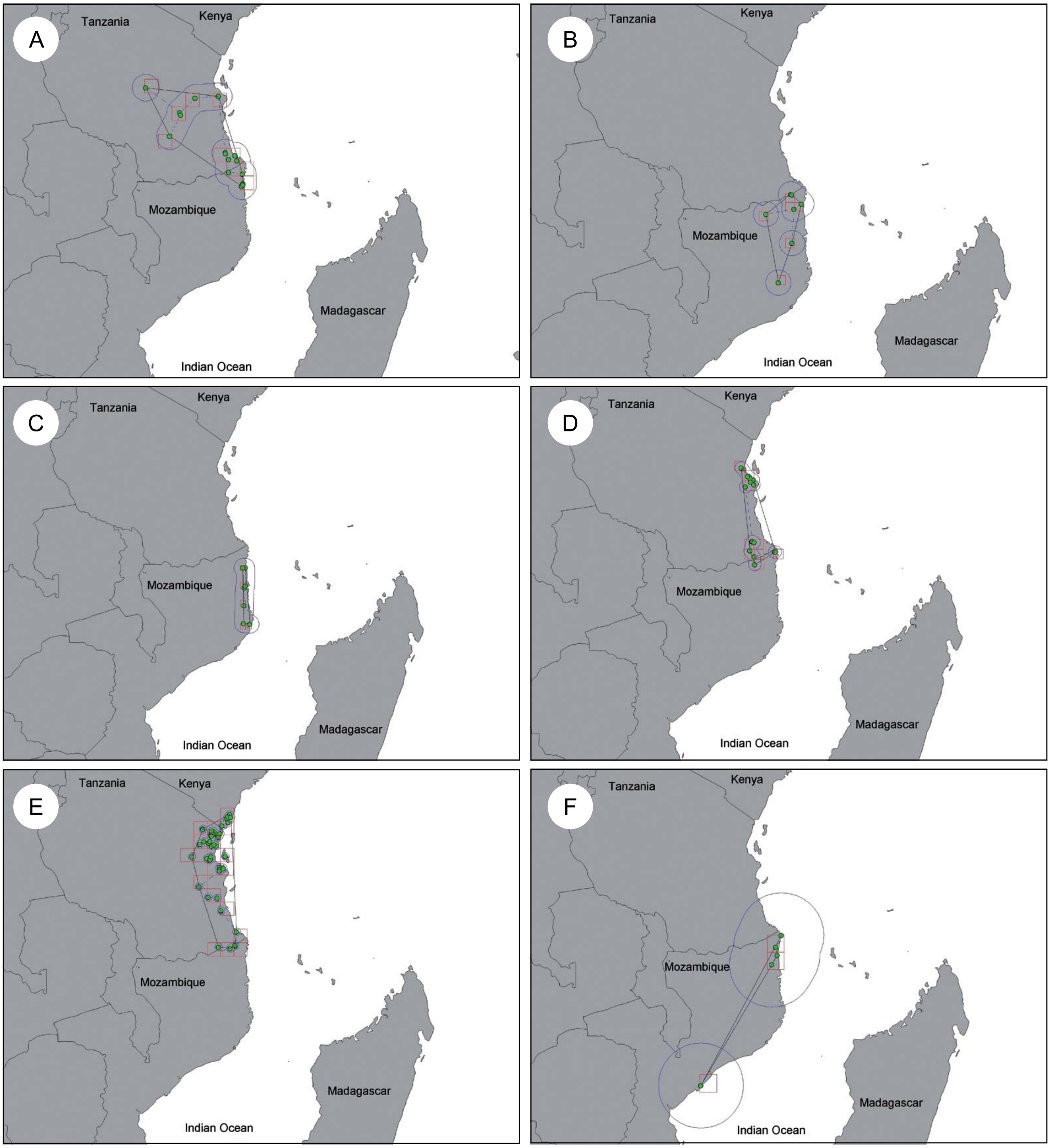
Table 3 – Number of taxa from the main plant families found in the Cabo Delgado study.

family	no. taxa	no. new species	no. new Moz records
Aracaeae	12	1	4
Orchidaceae	11	-	5
Acanthaceae	18	-	2
Annonaceae	23	2	5
Apocynaceae	28	-	2
Asteraceae	11	2	1
Capparaceae	19	-	2
Celastraceae	14	1	1
Combretaceae	17	-	-
Ebenaceae	12	-	3
Euphorbiaceae	41	1	3
Lamiaceae	28	2	3
Leg.: Caesalpinioideae	24	-	2
Leg.: Mimosoideae	29	1	1
Leg.: Papilionoideae	43	2	3
Rubiaceae	83	13	8
Rutaceae	9	2	2
Sapindaceae	12	1	1
Sterculiaceae	11	2	-
Tiliaceae	12	-	1
Vitaceae	6	-	2

Table 4 – New records for Mozambique from Cabo Delgado study area, 2003–2009.

monocotyledons
Amaryllidaceae
Crinum aurantiacum Lehmiller
Anthericaceae
Chlorophytum amplexicaule Baker
Araceae
Amorphophallus maximus (Engl.) N.E.Br. subsp. *fischeri* (Engl.) Govaerts & Frodin
Anchomanes abbreviatus Engl.
Culcasia orientalis Mayo
Stylochaeton euryphyllus Mildbr.
Arecaceae
Hyphaene petersiana Mart.
Dracaenaceae
Sansevieria cf. *metallica* Gérôme & Labroy
Orchidaceae
Eulophia acutilabra Summerh.
Eulophia guineensis Lindl.
Microcoelia megalorrhiza (Rchb.f.) Summerh.
Microcoelia physophora (Rchb.f.) Summerh.
Nervilia bicarinata (Blume) Schltr.
dicotyledons
Acanthaceae
Lepidagathis plantaginea Mildbr.
Whitfieldia orientalis Vollesen
Anacardiaceae
Lannea schweinfurthii (Engl.) Engl. var. *acutifolia* (Engl.) Kokwaro
Annonaceae
Artabotrys modestus Diels subsp. *macranthus* Verdc.
Lettowianthus stellatus Diels
Monanthotaxis faulknerae Verdc.
Monanthotaxis trichantha (Diels) Verdc.
Monodora minor Engl.& Diels
Apocynaceae
Baissea myrtifolia (Benth.) Pichon
Cryptolepis hypoglauca K.Schum.
Asteraceae
Vernonia zanzibarensis Less.
Balanitaceae
Balanites maughamii Sprague subsp. *acuta* Sands
Burseraceae
Commiphora fulvotomentosa Engl.
Commiphora pteleifolia Engl.
Capparaceae
Maerua bussei (Gilg & Gilg-Ben.) Wilczek
Ritchiea capparoides (Andr.) Britton var. *capparoides*
Celastraceae
Elaeodendron buchananii (Loes.) Loes.
Connaraceae
Vismianthus punctatus Mildbr.
Cucurbitaceae
Peponium leucanthum (Gilg) Cogn.
Ebenaceae
Diospyros kabuyeana F.White

dicotyledons
Ebenaceae
Diospyros magogoana F.White
Diospyros shimbaensis F.White
Euphorbiaceae
Croton polytrichus Pax subsp. *polytrichus*
Drypetes sclerophylla Mildbr.
Omphalea mansfieldiana Mildbr.
Lamiaceae
Orthosiphon scedastophyllus A.J.Paton
Premna gracillima Verdc.
Premna hans-joachimii Verdc.
Leguminosae: Caesalpiniodeae
Scorodophloeus fischeri (Taub.) J.Léonard
Senna auriculata (L.) Roxb.
Leguminosae: Mimosoideae
Newtonia paucijuga (Harms) Brenan
Leguminosae: Papilionoideae
Dalbergia lactea Vatke
Erythrina haerdii Verdc.
Erythrina sacleuxii Hua
Loganiaceae
Strychnos xylophylla Gilg
Myrtaceae
Eugenia capensis (Eckl.& Zeyh.) Sond. subsp. *multiflora* Verdc.
Ochnaceae
Ochna ovata F.Hoffm.
Passifloraceae
Adenia kirkii (Mast.) Engl.
Rubiaceae
Coffea schliebenii Bridson (Coffea sp. D of FTEA)
Gardenia transvenulosa Verdc.
Kraussia kirkii (Hook.f.) Bullock
Leptactina papyrophloea Verdc.
Pavetta lindina Bremek.
Rhodopentas parvifolia (Hiern) Kårehed & B.Bremer
Rothmannia macrosiphon (Engl.) Bridson
Vangueria cf. *randii* S.Moore subsp. *vollesenii* Verdc.
Rutaceae
Vepris sansibarensis (Engl.) Mziray
Zanthoxylum lindense (Engl.) Kokwaro
Sapindaceae
Haplocoelum inoploeum Radlk.
Thymelaeaceae
Synaptolepis kirkii Oliv. sensu stricto
Tiliaceae
Grewia stuhlmannii K.Schum.
Violaceae
Rinorea welwitschii (Oliv.) Kuntze subsp. *tanzanica* Grey-Wilson
Viscaceae
Viscum gracile Polhill & Wiens
Vitaceae
Cissus phymatocarpa Masinde & L.E.Newton
Cissus sylvicola Masinde & L.E.Newton



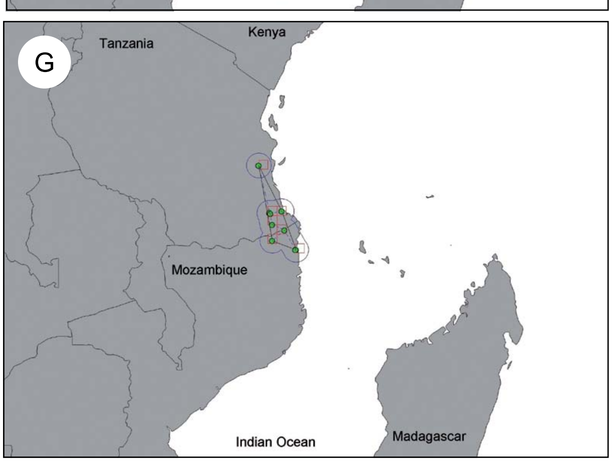


Figure 3 – Distribution records of selected coastal species. A, *Guibourtia schliebenii*; B, *Hexalobus mossambicensis*; C, *Micklethwaitia carvalhoi*; D, *Monodora minor*; E, *Scorodophloeus fischeri*; F, *Thespesia mossambicensis*; G, *Vismianthus punctatus*. Black line = extent of occurrence (EOO); red squares = area of occupancy (AOO) using 4 km^2 grid; blue polygon = extent of subpopulations using Rapoport's mean propinquity technique.

Table 5 – Global IUCN Red Data status for seven selected Eastern African dry forest species and 2010 assessments from the East African Plant Red List Authority (EAPRLA).

family/species	No. records	EOO (km²)	AOO (4 km² cell)	status	EAPRLA assessment
Annonaceae					
Hexalobus mossambicensis N.Robson	11	45,043	28	EN	-
Monodora minor Engl. & Diels	23	54,062	68	EN	NT
Connaraceae					
Vismianthus punctatus Mildbr.	11	22,864	40	EN	VU B1ab(iii)+2ab(iii)
Leguminosae: Caesalpinioideae					
Guibourtia schliebenii (Harms) J.Léonard	18	164,778	64	EN	VU B2ab(ii,iii,iv,v)
Micklethwaitia carvalhoi (Harms) G.P.Lewis & Schrire	8	9,502	28	EN	-
Scorodophloeus fischeri (Taub.) J.Léonard	72	137,578	212	EN	LC
Malvaceae					
Thespesia mossambicensis (Exell & Hillc.) Fryxell	5	16,416	20	EN	-

sambicensis (Exell & Hillc.) Fryxell], one shows a Cabo Delgado–Lindi distribution (*Vismianthus punctatus* Mildbr.), and three show a somewhat broader Tanzania–Mozambique coastal distribution [*Monodora minor* Engl. & Diels, *Guibourtia schliebenii* and *Scorodophloeus fischeri* (Taub.) J.Léonard], although *Guibourtia* is also found inland on the Eastern Arc mountains and *Scorodophloeus* is also found in coastal Kenya.

During the identification process it was noted that twelve taxa were endemic to coastal northern Mozambique (area Moz N: of Flora Zambesiaca) plus around nineteen of the new species. There are 53 taxa known primarily from northern Mozambique and adjacent areas of south-east Tanzania (area T8 of Flora of Tropical East Africa), showing the strong links between them. Most of these appear to be local endemics. A further 46 taxa appear to be at the southern end of their East African (Swahilian) distribution in Cabo Delgado.

It is also apparent that species in miombo and similar woodland types, fallows, grassland and wetlands, are far more widespread than those from dry forests. Many of them are found across the Miombo Ecoregion of south central Africa (Timberlake & Chidumayo 2001) or even more widely, e.g. *Afzelia quanzensis* Welw., *Brachystegia spiciformis* Benth., *Parinari curatellifolia* Benth., *Pseudolachnostylis maprouneifolia* Pax and *Uapaca nitida* Müll.Arg., in marked contrast to the local distribution of so many dry forest species. An interesting exception is *Berlinia orientalis* Brenan that commonly occurs in fallows and miombo woodland (and sometimes in dry forest), but which is known only from a limited area of Cabo Delgado across to south-east Tanzania (Luke 2004).

Future work will probably confirm these distribution patterns and show the very marked East African coastal element in the overall distribution of the dry forests of the study area, with particularly strong links to that found with the Lindi–Mtwara region of south-east Tanzania, while also showing that woodland and grassland flora species have a much wider distribution.

Red Data assessments

Preliminary conservation assessments to determine IUCN Red Data List categories were carried out on the seven woody species used to map distribution patterns. All were chosen primarily for their known restricted coastal distribution patterns or ecological importance and because there were adequate data points.

By using the Kew GIS Unit's extension tool (www.kew.org/gis/projects/cats/catsdoc.pdf), rapid conservation assessments based on IUCN categories and criteria were produced (IUCN 2008). Data points were derived from collections made during this study and from historic specimens held at Kew, those available from the African Plants Initiative (http://plants.jstor.org) and from Missouri Botanic Garden's Tropicos database (http://www.tropicos.org), which includes specimens from the East African Herbarium (EA). The assessments calculate the Extent of Occurrence (EOO), Area of Occurrence (AOO), number of sub-populations and number of locations (table 5). The cell size used for AOO was 4 km² (2 × 2 km), recommended by IUCN (2008) for restricted distribution species.

From the individual species assessments, distribution maps were compiled (fig. 3) and the species' IUCN status (IUCN 2001) determined (table 5). By using the default 4 km² cell size all species were assessed as being Endangered (EN). If a larger cell sizes were used (e.g. 35–85 km sides), the threat status decreased in most cases to Least Concern. Of the seven species, the most narrowly distributed was the Mozambique endemic *Thespesia mosambicensis*, occurring in only twenty cells, while the other Mozambique endemics *Hexalobus mossambicensis* and *Micklethwaitia carvalhoi* were recorded from just 28 cells. *Scorodophloeus fischeri*, found from northern Mozambique to southern Kenya, was found in 212 cells. As the process is automated, this can lead to some odd maps, such as in fig. 3F. Here two obviously separate populations are artificially linked by the EOO, which is more an indication of the spread of risk. In this case the restricted AOO should be regarded as the more definitive indication of distribution and risk.

Conservation assessments are already available on the IUCN Red List website (http://www.iucnredlist.org) for three of these species – *Guibourtia schliebenii* (VU B1+2b), *Hexalobus mossambicensis* (DD) and *Monodora minor* (Near Threatened) – the first two dating from 1998 before much information was available for the Mozambique populations. Recently, four of the seven species above were assessed by the East African Plant Red List Authority (EAPRDA, Q. Luke, pers. comm.) with results shown in table 5. In three cases the assessments were lower, probably as more local information was available on their status in Tanzania and Kenya. Of particular note is *Scorodophloeus*, which the EAPRDA assessed as Least Concern rather than Endangered.

Although the preliminary assessments are based solely on recorded past and present distributions derived from herbarium specimens, we know the habitat is under marked threat, hence the Endangered status may be appropriate for some species. It is likely that a number of other dry forest species, once assessed, will have a similar threat status. In contrast, the great majority of species associated with woodland across the study area are known to have a much wider sub-continental distribution and will likely be assessed as Least Concern.

CONTEXT AND CONSERVATION

Regional context

Across south-central Africa numerous, generally small (less than 20 km^2) patches of dry forest can be found within the matrix of miombo or similar Caesalpinoid-dominant woodland types (Timberlake & Chidumayo 2001, Frost et al. 2002). Examples are the extensive *Cryptosepalum exfoliatum* De Wild. forests of north-west Zambia (Fanshawe 1973, Burgess et al. 2004a, type 32); the Itigi thickets in central Tanzania dominated by *Baphia burttii* Baker f., *B. massaiensis* Taub., *Combretum celastroides* M.A.Lawson and *Bussea massaiensis* (Taub.) Harms. (Burtt 1942, Burgess et al. 2004a, type 48); similar forests around Lake Mweru Wantipa in north-east Zambia; forest patches dominated by *Xylia torreana* Brenan in the middle Zambezi valley and northern Zimbabwe (Timberlake et al. 1993, type C2); and patches characterized by *Guibourtia conjugata* (Bolle) J.Léonard on Cretaceous sands in south-eastern Zimbabwe and the northern Kruger National Park in South Africa. Sometimes termed 'sand forests' these vegetation types are primarily found on unconsolidated medium to coarse-textured sandy soils (often acidic) in the higher part of the catena.

Such dry forests show much similarity to many of the coastal forest patches seen in Cabo Delgado, particularly as regards the substrate, geomorphological position and in the families and even genera of characteristic plant species. As with coastal forests, there is a characteristic change in species composition across an area, and always a marked difference in species composition compared to that of the surrounding woodlands. In addition, many canopy species of dry forests of the continental interior are also early-deciduous with scattered sclerophyllous evergreen species in the understorey. With disturbance dry forest tends towards thicket, as can be clearly seen with the 'jesse bush' of the mid-Zambezi valley and in the Itigi thickets.

This raises an interesting question of whether all these dry forests – coastal and those on the old African plateau of the continental interior – are remnants of an earlier drier period, or whether it is a case of convergent evolution of vegetation type. However, coastal dry forests do show much higher levels of endemism and contain more species of restricted coastal distribution compared to those of the interior. For the coastal forests it is not clear if the species are relictual or, alternatively, what the driver might have been for their evolution given the relatively recent age of these patches in the landscape. The soils on which they are found are generally not old and infertile, as is the case with other areas of high endemism such as the Chimanimani mountains, Mt. Mulanje or the sandstones of the Cape mountains.

Conservation

The coastal strip of this part of Cabo Delgado has been settled for hundreds of years. Slave trading was significant during the 19th century and there was much trade at that time in ivory, gum copal (from *Hymenaea verrucosa* Gaertn.) and 'wild rubber' (*Landolphia* spp.). During the 20th century, in particular after the Second World War, there was extensive exploitation of timber by the Portuguese colonial authorities, focussing primarily on *Pterocarpus angolensis* Harms (Umbila), *Afzelia quanzensis* (Chanfuta), *Dalbergia melanoxylon* Guill. & Perr. (Pau-preto), *Milicia excelsa* (Welw.) C.C.Berg (Tule, Mvule), *Millettia stuhlmannii* Taub. (Jambiri, panga panga) and *Swartzia madagascariensis* Desv. (Pau-ferro), the effects of which can still be seen today (Timberlake et al. 2010).

Although many people moved out of rural areas during the independence struggle and civil war years (1960s to 1991), they are now starting to reoccupy many parts of the interior. This has been helped by better roads and transportation, including the construction of cut-lines during recent (2008) geophysical prospecting for oil, the sinking of wells and boreholes, and an influx of settlers from adjacent parts of Tanzania. The biggest threats to coastal forests at present are the rapid and uncontrolled clearance for subsistence agriculture, which is increasingly moving away from the main roads, logging (much of it illegal), and uncontrolled fires associated with settlement.

There is no formal protection of any coastal forest patches in Cabo Delgado except for a very small extent (less than 25 km^2) inside the newly-proclaimed Quirimbas National Park. Given their characteristic features – the high turnover in species composition between patches, which often makes each patch unique, and the number of species with very restricted distributions – it is difficult to identify a 'typical' area for conservation protection or to cover the full range of important species in just a few areas.

Timberlake et al. (2010) have described fourteen areas of importance for conservation of coastal forests and associated vegetation types from across the study area. These cover the more diverse and intact areas identified so far and also various sites containing species of interest. Four sites (Pundanhar–Nangade, Rio Macanga–Nhica do Rovuma, Quiterajo, Lupangua) are considered high priority. What is apparent is that in the northern parts along the Rovuma escarpment, landscape-level conservation would be the most appropriate, covering dry forest, dense woodland, wooded grassland and the large seasonal pans – an ecosystem approach. This area is also a major source of water for coastal towns. Further south, where settlement is much denser, a site approach would be more appropriate, for example the raised plateau with *Guibourtia schliebenii* forest in the Quiterajo concession south of the Messalo River.

Current research at RBG Kew and IIAM, Maputo is attempting to identify Important Plant Areas across the broad study area. Once zoological findings from recent surveys are available it is planned to incorporate these in order to identify Key Biodiversity Areas. Such identified and documented areas will be brought to the attention of government and provincial authorities in Mozambique, who have already indicated interest in the study.

CONCLUSIONS AND FUTURE STUDIES

Although the area studied in detail was limited in extent, compounded by difficulties in access over much of it, some conclusions on the extent, distribution and biodiversity of coastal forests in northern Mozambique can be drawn.

1. Coastal forests similar to those in south-eastern Tanzania are present, but are far less extensive than had previously been suggested. The present extent of dry forest is around 400 km^2, although this may well be an over-estimate. Parts of this are now being rapidly cleared for agriculture.
2. Most of the forest patches seen are relatively small and confined to deeper, well-drained sandy soils, most apparently derived from the Mikindani sandstone formation. They are surrounded by woodland vegetation dominated by typical miombo species such as *Brachystegia*, other caesalpinoids and some Euphorbiaceae trees, species that (with the exception of the coastal *Berlinia orientalis*) are mostly very widely distributed across the sub-continent.
3. The forests generally comprise an upper canopy of deciduous species, many from the Caesalpinioideae (e.g. *Guibourtia schliebenii*, *Hymenaea verrucosa*, *Micklethwaitia carvalhoi*), with sclerophyllous evergreen species in the sub-canopy (e.g. *Manilkara* spp., *Warneckea sansibarica*, *Baphia macrocalyx*). The shrub layer is particularly rich in Rubiaceae. A surprisingly high proportion of these species have quite restricted ranges or are local endemics, being confined to parts of the coastal regions of southern Kenya, Tanzania and northern Mozambique. Many are confined to the Lindi–Mtwara–Cabo Delgado area, the so-called Lindi centre of endemism in the Swahilian regional centre of endemism (Clarke 1998, 2001). It is this attribute – the high proportion of range-restricted species – that gave rise to the discovery of so many new species and Mozambique records.
4. Despite the name, such coastal forests do not contain mesic evergreen species and show little similarity in composition or ecology to moist forests in the region, whether montane or lowland.
5. Another interesting feature is the high turn-over in species composition between forest patches. Most patches appear to be unique, and there is no species that is characteristic or found in most of them, the closest being *Pteleopsis myrtifolia* (Combretaceae). Each patch appears to have a different dominant and suite of associates. This feature is either related to subtleties in the mineralogical or moisture status of the substrate, or could be solely an artefact of serendipity – the first species to arrive taking over.
6. The coastal forests are essentially ‘sand forests’ and, in many cases, show marked similarity in their structure, ecology and family (even generic) composition to areas of dry forest or thicket found on well-drained sandy soils across much of south-central Africa.
7. The high proportion of range-restricted species, the limited extent of the forest patches, and the increased threat, show that the coastal forests of northern Mozambique should be of international conservation concern. The possibilities of landscape or ecosystem-level conservation are now very limited, so attention also needs to be given to the selection of a range of sites across Cabo Delgado in order to conserve the full range of forest types and species.

The origins and affinities of these coastal dry forests, as well as determination of what the drivers for the marked levels of speciation and endemism might have been, remain important areas for research. But perhaps more urgent at this stage is continued documentation of the extent of coastal forests in other parts of Mozambique and the development of practical conservation measures needed to protect a rapidly disappearing vegetation type.

ACKNOWLEDGEMENTS

We would like to thank Pro Natura International and the Muséum National d’Histoire Naturelle, Paris, for organising the expeditions under their Our Plant Reviewed programme, and the Prince Albert II of Monaco Foundation, the Stavros Niarchos Foundation and the Total Foundation for funding. Much help in the field was given by Salim Annebi, Aurelio Banze, Sandie Burrows, Mervyn Lotter, Patricia Luke, Alice Massingue, Frédéric Mathias and Barbara Turpin. Field support and logistics during the expedition were ably provided by Mike Scott and his team from Khangela Safaris, Bulawayo, while Charlie Mackie provided aerial reconnaissance. We are particularly grateful to Iain Darbyshire and Tim Harris of the Drylands Africa team at RBG Kew for assistance in plant identification; Aaron Davis, Diane Bridson and the Rubiaceae team, Gill Challen, Martin Cheek, Anna Haigh, Ana-Claudia Araujo and Paul Wilkin also made valuable contributions. Erik Prins produced the satellite images and Justin Moat of the Kew GIS Unit helped prepare the maps. Neil Burgess and an anonymous reviewer made valuable comments on an earlier version of the paper.

REFERENCES

Bidgood S., Vollesen K. (1992) Bauhinia loeseriana reinstated, with notes on the forests of the Rondo Plateau, S.E. Tanzania. Kew Bulletin 47: 759–764.

Brenan J.P.M. (1978) Some aspects of the phytogeography of tropical Africa. Annals of the Missouri Botanical Garden 65: 437–478. doi:10.2307/2398859

Burgess N.D., Clarke G.P. (eds) (2000) Coastal Forests of Eastern Africa. Cambridge, IUCN Publications.

Burgess N.D., Clarke G.P., Madgwick J., Robertson S.A., Dickinson A. (2000) Distribution and status. In: Burgess N.D., Clarke G.P. (eds) Coastal Forests of Eastern Africa: 71–81, 344. Cambridge, IUCN Publications.

Burgess N., D'Amico Hales J., Underwood E., Dinerstein E., Olson D., Itoua I., Schipper J., Ricketts T., Newman K. (2004a) Terrestrial ecoregions of Africa and Madagascar: a conservation assessment. Washington, Island Press & WWF US.

Burgess N., Salehe J., Doggart N., Clarke G.P., Gordon I., Sumbi P. Rodgers A. (2004b) Coastal Forests of Eastern Africa. In: Mittermeir R.A., Gil P.R., Hoffmann R., Pilgrim J., Brooks T., Mittermeir C.G., Lamoreux J., Da Fonseca G.A.B. (eds) Hotspots revisited: Earth's biologically richest and most endangered ecosystems: 231–239. Washington, Conservation International and Mexico, Cemex.

Burrows J.E. (2009) Tarenna pembensis and Pavetta curalicola, two new species of Rubiaceae from northern Mozambique. Kew Bulletin 64: 689–693. doi:10.1007/s12225-009-9160-0

Burrows J.E., Burrows S.M. (2010) A new species of Didymosalpinx and a new species of Oxyanthus (Rubiaceae) from Mozambique and Tanzania. Bothalia 40: 200–204.

Burtt B.D. (1942) Some East African vegetation communities. Journal of Ecology 30: 65–145. doi:10.2307/2256690

Clarke G.P. (1998) A new regional centre of endemism in Africa. In: Huxley C.R., Lock J.M., Cutler D.F. (eds) Chorology, taxonomy and ecology of the Floras of Africa and Madagascar: 53–65. London, Royal Botanic Gardens, Kew.

Clarke G.P. (2000a) Defining the eastern African coastal forests. In: Burgess N.D., Clarke G.P. (eds) Coastal forests of Eastern Africa: 9–26. Cambridge, IUCN Publications.

Clarke G.P. (2000b) Climate and climatic history. In: Burgess N.D., Clarke G.P. (eds) Coastal Forests of Eastern Africa: 47–67. Cambridge, IUCN Publications.

Clarke G.P., Vollesen K., Mwasumbi L.B. (2000) Vascular plants. In: Burgess N.D., Clarke G.P. (eds) Coastal Forests of Eastern Africa: 129–147. Cambridge, IUCN Publications.

Clarke G.P. (2001) The Lindi local centre of endemism in SE Tanzania. Systematics and Geography of Plants 71: 1063–1072. doi:10.2307/3668738

Degreef J. (2006) Revision of continental African Tarenna (Rubiaceae-Pavetteae). Opera Botanica Belgica 14. Meise, National Botanic Garden of Belgium.

Fanshawe D.B. (1973) The vegetation of Kabompo District. Forest Research Pamphlet No. 55. Kitwe, Zambia Forest Research Department.

Frost P.G.H., Timberlake J.R., Chidumayo E. (2002) Miombo–Mopane woodlands and grasslands. In: Mittermeir R.A., Mittermeir C.G., Gil P.R., Pilgrim J., Da Fonseca G.A.B., Brooks T., Konstant W.R. (eds) Wilderness: Earth's last wild places: 183–204. Washington, Conservation International and Mexico, Cemex.

Greenway P.J. (1973) A classification of the vegetation of East Africa. Kirkia 9: 1–68.

Hawthorne W.D. (1993) East African coastal forest botany. In: Lovett J.C., Wasser S.K. (eds) Biogeography and ecology of the rain forests of Eastern Africa: 57–99. Cambridge, Cambridge University Press.

ING (1987) Carta Geológica, scale 1: 1 million. Maputo, Instituto Nacional de Geologia.

IUCN (2001) IUCN Red List Categories and Criteria. Version 3.1. Gland & Cambridge, IUCN Species Survival Commission.

IUCN (2010) The IUCN Red List of Threatened Species. Version 2010.4. Available at http://www.iucnredlist.org. [accessed 30 January 2011.]

IUCN Standards and Petitions Working Group (2008) Guidelines for using the IUCN Red List Categories and Criteria. Version 7.0. Prepared by Standards & Petitions Working Group of IUCN SSC Biodiversity Assessments Sub-Committee, August 2008. Available at http://intranet.iucn.org/webfiles/doc/SSC/RedList/RedListGuidelines.pdf [accessed 23 Mar. 2011].

Kassam A.H., Van Velthuizen H.T., Higgins G.M., Christoforides A., Voortman R.L., Spiers B. (1981) Climatic data bank and length of growing period analysis. Field Document no. 33, FAO MOZ/75/011, Assessment of Land Resources for Rainfed Crop Production in Mozambique. Rome, FAO.

Luke W.R.Q. (2004) Rapid assessment of terrestrial plant diversity of Mnazi Bay–Ruvuma Estuary Marine Park, Tanzania. Unpublished report. Nairobi, IUCN EARO.

Luke W.R.Q. (2006) Botanical investigation southern Tanzania/northern Mozambique. Unpublished report. Nairobi, WWF & CI.

Moomaw J.C. (1960) A study of the plant ecology of the coast region of Kenya, East Africa. Nairobi, Kenya Dept. of Agriculture/EAAFRO.

Myers N., Lovett J.C., Burgess N.D. (1999) Eastern Arc Mountains and Coastal Forests. In: Mittermeir R.A., Myers N., Gil P.R., Mittermeier C.G. (eds) Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions: 205–217. Washington, Conservation International and Mexico, Cemex.

Pedro J.G., Barbosa L.A.G. (1955) A Vegetação. In: Esboço da Vegetação Ecológico-Agricola de Moçambique pela Junta de Exportação do Algodão em Moçambique. CICA Memorias e Trabalhos 23. Lourenço Marques, Mozambique.

Robertson S.A., Luke W.R.Q. (1993) Kenya Coastal Forests. Report on NMK/WWF Coast Forest Survey, WWF Project 3256. Nairobi, WWF International.

Timberlake J.R., Chidumayo E. (2001) Miombo Ecoregion: vision report. Unpublished report. Harare, WWF SARPO.

Timberlake J.R., Goyder D.J., Crawford F.M., Pascal O. (2010) Coastal dry forests in Cabo Delgado: Botany/Vegetation. Unpublished report. London, Royal Botanic Gardens, Kew and Paris, Pro Natura International.

Timberlake J.R., Nobanda N., Mapaure I. (1993) Vegetation survey of the communal lands – north and west Zimbabwe. Kirkia 14: 171–270.

Vollesen K. (1994) Rondo Plateau, Tanzania. In: Davis S.D., Heywood V.H., Hamilton A.C. (eds) Centres of plant diversity: a guide and strategy for their conservation: 225–226. Cambridge, UK, IUCN Publications.

White F. (1983) The vegetation of Africa. Natural Resources Research 20. Paris, UNESCO.

Wild H., Barbosa L.A.G. (1967) Vegetation map of the Flora Zambesiaca area. Supplement to Flora Zambesiaca. Salisbury, M.O. Collins.

WWF-EARPO (2006) Eastern Africa Coastal Forests Ecoregion. Strategic Framework for Conservation 2005–2025. Nairobi, WWF-EARPO.

Paper based on results presented during the XIXth AETFAT Congress (Madagascar 2010). Manuscript received 30 Sep. 2010; accepted in revised version 15 Feb. 2011. This paper will be reprinted in the Proceedings of the XIXth AETFAT Congress.

Communicating Guest Editor: Mats Thulin.