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COMMENTARY

East African coastal forest under pressure

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Abstract The Arabuko Sokoke dryland coastal forest along the East African coastline provides a unique habitat for many endangered endemic animal and plant species. High demographic pressure with subsequent land-splitting, soil depletion in combination with erratic rainfalls and the collapse of the tourism industry are negatively affecting food security and human livelihood quality in this region. Food crops were originally produced by subsistence farming, but have now to be purchased at local- and super-markets, constituting a major financial burden for the local people. In consequence, overexploitation of natural resources from Arabuko Sokoke forest (illegal logging, charcoal burning, poaching of wild animals) increased during the past years. In this commentary we document ecosystem heterogeneity leading to high species richness. We discuss direct and indirect drivers of habitat degradation of the Arabuko Sokoke forest, and critically reflect current and future solutions. Key drivers of habitat destruction and biodiversity loss are (i) illegal timber logging and removal of woody biomass, (ii) poaching of bush-meat, (iii) exceeding

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of the carrying capacity by the local elephant population, restricted to Arabuko Sokoke by an electric fence, and (iv) weak governance structures and institutional confusion exacerbating illegal exploitation of natural resources. Potential solutions might be: Provisioning of additional income sources; reforestation of the surrounding areas in the framework of REDD+ activities to create a buffer around the remaining primary forest; improving governance structures that formulates clear guidelines on future usage and protection of natural resources within the Arabuko Sokoke forest; and family planning to counteract human demographic pressure and the exploitation of natural resources.

Keywords Biodiversity hotspot · Disturbances · Endemism · Exploitation · Poverty · Natural resources · Governance structures

East African coastal forest—unique and threatened

The East African coastal forest runs along the Tanzanian and Kenyan coast, from Somalia in the north to Mozambique in the south. This region constitutes one of the 35 global biodiversity hotspots (Mittermeier et al. 2009) and comprises highest diversity of endemic plant and animal species (Burgess et al. 1998; Matiru 1999; Muriithi and Kenyon 2002). Despite its biological relevance, this region has undergone a long history of anthropogenic destruction and disturbance, since the colonial era. This millennial use has transformed the endogenous forest cover to a set of small remnant patches (Burgess et al. 1998). Today, only approximately 3170 km^2 of East Africa's coastal forest still exists (about 21% of the total remaining coverage) (Azeria et al. 2007; Wegner et al. 2009). 660 km^2 of its total coverage is restricted to Kenya, split into various forest patches (Burgess et al. 1998), underlying divergent conservation regimes (Tabor et al. 2010).

The Arabuko Sokoke forest (hereafter referred to as ASF) is the largest remaining forest patch of indigenous dry coastal forest of Kenya with a total forest size of approximately 416 km^2 (ASFMT 2002), surrounded by other forest patches (Dakatcha Woodlands, Shimba Hills, Boni, Witu, Dodori, and the sacred Kayas) (Matiku et al. 2013). ASF consists of at least three different forest types according to tree species composition and dominant plant taxa, related to the distribution of soil texture (*Cynometra* forest, *Brachystegia* forest, mixed forest) (Muriithi and Kenyon 2002). Forest type classification has been changing over time, reflecting continuous transformation that this forest is undergoing due to anthropogenic disturbance.

The core area of the ASF extends over 42.2 km^2 and is protected by nature reserve status since 1960, buffered by 372.48 km^2 of forest reserve. There exist at least 52 villages around ASF with a total population of more than 104,000 people, most of them depending on subsistence agriculture (ASFMT 2002; Ongugo et al. 2008). The region is characterized by a high human population density (229.1 people/km^2; compared to 74.8 people/km^2 in the coastal region or a mean of 66.4 people/km^2 across Kenya) (KNBS Census 2009). High human population growth rates by more than 4.4% (calculated for Kilifi and Malindi county between 1999 and 2009, KNBS Census 2009) is causing a high pressure on natural resources and pristine habitats, including the ASF (Oyugi et al. 2007). This situation of resource depletion across this region including the ASF becomes further aggravated due to the fact that all people living within a 5 km buffer zone around ASF have the legal right to

benefit from natural resources provided by the forest (Matiku et al. 2013). In the following we will analyse kinds of destruction and disturbances of ASF and will critically reflect ongoing and new strategies to preserve this biodiversity hotspot for future generations.

From global to local

According to weather records, rainfall patterns changed during the past decades, apparently as a consequence of the El Nino Southern Oscillation (ENSO) phenomenon. Daily rainfall patterns for a representative weather station of Kilifi (10 km south-east of ASF) encompass data from nearly 60 years (1930–1988). The duration of growing periods (the Agro-Humid-Period, AHP) (cf. Müller 2003; Hornetz 2012) became shorter and more eratic, with longer periods of dryness and increasing unpredictability of percipitation especially during the second rainy season (Jaetzold et al. 2012). At the same time, the number of wet ENSO seasons increased during the last 40 years, probably due to the global warming phenomenon (Jaetzold et al. 2012). The ENSO phenomenon is apparently influencing the performance of the Somali/East African low level jet in some years (Muti and Kibe 2009) being responsible for dry spells with windy conditions during the first rainy season (long rains) and the delay of crop growth, particularly during the yield sensitive periods of tasselling (e.g. of maize).

These global climatic changes caused a reduction of yields of food crops with negative effects on food security. Thus, today, people are forced to substitute their food crops by products purchased from local- and super-markets, which imply a higher dependency on financial sources frequently derived from illegal harvesting and selling of natural resources from ASF, like logging hardwood for poles, timber, carving and charcoal burning. This

Table 1 Three forest types with characteristic plant species and its degree of endangerment (according to IUCN classification), and kind of use

Vegetation type	Species	IUCN category	Uses
Cynometra forest	*Brachylaena huillensis*	Near threatened	Carving, timber, firewood, charcoal, poles
	Cynometra webberi	Vulnerable	Carving
	Euphorbia candelabrum	Not listed	Traditional use
	Manilkara sulcata	Not listed	Firewood, timber, carving
	Oldfieldia somalensis	Not listed	Not described
Brachystegia forest	*Brachystegia spiciformis*	Not listed	Firewood, charcoal, timber
Mixed forest	*Afzelia quanzensis*	Not listed	Timber, poles
	Combretum schumannii	Not listed	Firewood, charcoal, timber, carving
	Drypetes reticulata	Not listed	Charcoal, poles
	Encephalartos hildebrandtii	Near threatened	Ornamental purposes
	Hymenaea verrucosa	Not listed	Firewood, charcoal, timber
	Manilkara sansibarensis	Not listed	Firewood, timber, carving

dependency on alternative (i.e. illegal) money income becomes further aggravated by the collapsing tourism industry with subsequent lack of job opportunities along the Kenyan coast during the past years.

Waves of exploitation

The exploitation of hardwood timber in ASF reaches back to the 1920s, when *Brachylena huillensis*, *Afzelia quanzensis* and *Manilkara sansibara* were systematically logged by European sawmills (Moomaw 1960). Legal timber harvest continued with very little planned utilization, to the extent that by 1970 the stock was depleted to support commercial sawmills (Glenday 2008). Although there is no accurate data on volume of wood extracted, the effects of past commercial selective logging and continued removal of large trees of several species, has notoriously changed the species composition of the forest (Robertson and Luke 1993; Fanshawe 1995). Remaining hard wood tree species like *Cynometra webberi* and *Brachystegia spiciformis* become still exploited for wood carvings for the local and regional (tourism) market (Wass 1995) (Table 1).

However, particularly hardwood tree species of the ASF provide key-habitat requirements for many endemic and range-restricted species. Larvae of the butterfly species as *Charaxes lasti*, endemic to the east African coastal forest depends on the leaf of tree species such as *A. quanzensis* and *B. spiciformis* (Van Someren 1970). The Sokoke Scops Owl *Otus ireneae* is restricted to ASF and some adjacent unprotected regions in Kenya and

Table 2 Threatened animal species of ASF, with characteristic animal species, its degree of endangerment (according to IUCN classification), and kind of threats

Species	IUCN category	Main threat
Mammals		
Bdeogale omnivore[a]	Vulnerable	Bushmeat and habitat loss
Cephalophus adersi[a]	Critically endangered	Bushmeat
Rhynchocyon chrysopygus[a]	Endangered	Bushmeat and habitat loss
Birds		
Anthus sokokensis[a]	Endangered	Habitat loss
Geokichla guttata	Endangered	Habitat loss
Hedydipna pallidigaster[a]	Endangered	Habitat loss
Otus ireneae[a]	Endangered	Habitat loss
Ploceus golandi[a]	Endangered	Habitat loss
Sheppardia gunningi	Near threatened	Habitat loss
Amphibians		
Mertensophryne micranotis[a]	Least concern	Habitat loss
Insects		
Charaxes lasti[a]	Unknown	No specified
Charaxes protoclea[a]	Unknown	No specified
Baliochila latimarginata[a]	Unknown	No specified
Baliochila stygia[a]	Unknown	No specified

[a] Endemic or range-restricted species to ASF and the coastal a forest region

Tanzania (Evans 1997) and depends on dense *Cynometra* woodland with large trees (Virani et al. 2010). Unfortunately, these hardwood tree species has become a main target of illegal timber logging, with negative effects on many species, and the population trend of *O. ireneae*.

Apart from illegal logging and charcoal production, hunting of bush meat is the second component of illegal activities inside of ASF, with severe effects on small and geographically restricted populations of various vertebrate species (Fitzgibbon et al. 2009) (Table 2). Poaching activities are not homogenously distributed across ASF and concentrate to local regions, depending on the seasonal availability of resources and accessibility (Fig. 1). These disturbances occur independently from conservation regimes in ASF, as underlined by observed illegal use of resources also inside of the strictly conserved nature reserve.

Transgressing the carrying capacity

Although a number of studies indicate that fencing off areas may prevent human-wildlife conflicts (Anthony et al. 2010), this comes with various ecological problems, like the blockage of traditional migration routes of large animal species. To avoid human-wildlife conflicts and to restrict elephants to the forest, ASF was fenced. This has also impeded illegal settlement and complete deforestation inside the forest. However, the already debilitated ecosystem quality of ASF becomes currently further degraded by the local and very dense population of the African elephant *Loxodonta africana*. The fence around ASF spatially restricts this elephant population with detrimental effects on ecosystem health of the forest. This situation becomes further aggravated due to the fact that these elephants currently depend on one single artificial water source. This causes a strong concentration of individuals to a small section of the forest, producing high levels of ecosystem disturbances. Such high concentration of elephants causes the destruction of trees and intense tree debarking. This example underlines that fencing only partially helps to hold an ecosystem intact.

Weak governance and institutional confusion

Effective conservation strategies are hardly feasible due to weak governance structures and unclear responsibilities among stakeholders. The ASF management is split into four forest regions: Jilore, Gede, Sokoke and Kararacha, under management of three forest stations, Jilore, Gede and Sokoke. There exist about 300 governmental and non-governmental organizations being currently involved in the management of ASF (Ongugo et al. 2008; Ngala pers. comm.). This institutional diversity leads to confusion and unavoidable communication problems, and makes it virtually impossible to assign a clear and consistent conservation management strategy. Apart from problems at the local level, there are additional communication gaps within institutions and among national (Nairobi headquarters), county (Kilifi and Malindi), and local (the ASF headquarters) level. This lack of communication and confucsion creates an suitable climate for ongoing illegal exploitation of natural resources.

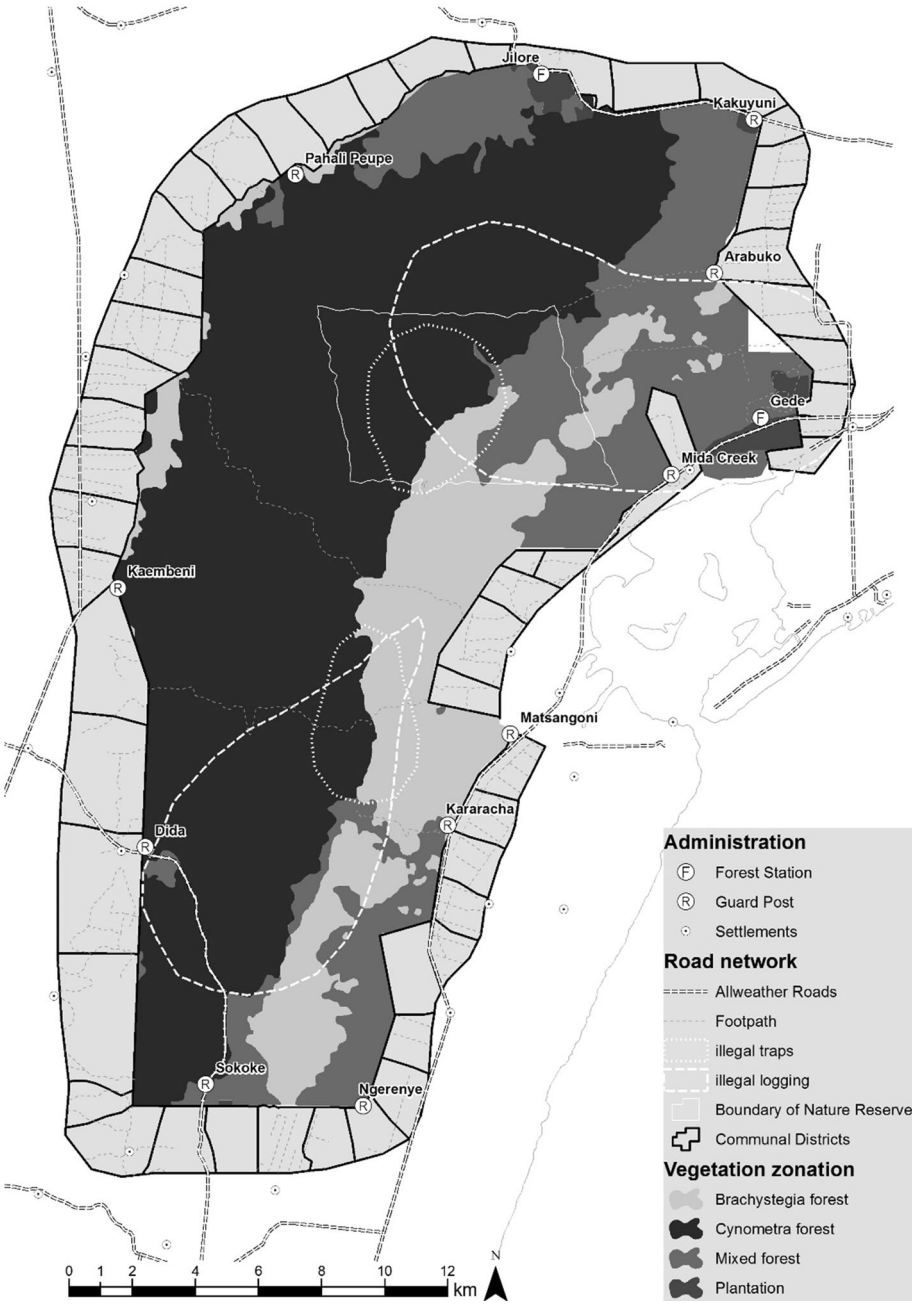

Fig. 1 The Arabuko Sokoke forest consisting of three forest types and surrounded by human settlements. Shown are hotspots of illegal logging (*dashed white lines*, 50% density kernels based on 344 and 132 points for illegal traps and logging assessed across the entire forest cover during the years 2015 and 2016, calculated with QGIS software

Diminishing the pressure

Conflicts between livelihood needs and nature conservation in and around ASF are multifaceted and driven from global, local and institutional factors. Provisioning of alternative income sources (beyond illegal logging, poaching of bush meat) might improve human livelihood. Various successful activities have already been established during the past: the Kipepeo project created by Birdlife 1994 provides a platform for more than 400 butterfly farmers to sell pupae (Gordon and Ayiemba 2003). The Nyuki project focuses on honey production by bee keeping. Further activities like the establishing of tree nurseries, production of extracts from Aloe plants, the cultivation of mushrooms, and the set-up of Jamii Villa environmental education centre are further examples of how to create alternative income sources around the forest (cf. Gordon 2003; Sinclair et al. 2011; Matiku et al. 2013). A recent strategy uses the *domino effect* so that revenues of successfully running community-based projects are used to start and invest into future community-based activities. This process is currently coordinated from the Arabuko Sokoke Forest Adjacent Dwellers Association (ASFADA), an umbrella group which also communicates problems of the surrounding villages, communities and conservation groups.

However, most of these activities only affect a small proportion of the local human population. Improved food production may help much more to live independently from additional (illegal) financial income. Resources (like charcoal and fire wood) should be used more efficiently by using cooking stoves. At the same time, existing zonation regimes in ASF should be adhered to much more strictly with proper law enforcement and community participation that embrace sustainable resource utilization. In this regard, specific managing agencies at the site could be assigned for specific zones to manage those, based on their mandates and capacity. A third-party stakeholder should control and guarantee the efficiency of activities, controlling and preventing corruption. Reforestation around ASF in the framework of REDD+ (Glenday 2008) (as already successfully implemented in other parts of Kenya, see the Kasigau corridor, Dinerstein et al. 2013) might create a strategic buffer for this very sensitive forest ecosystem; the cultivation of woodlots might pose a suitable concept. Finally, the most pressing factor might be family planning, i.e. to regulate and decrease demographic pressure and to lower the pressure on East African coastal forests in the near future.

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