POLICY PERSPECTIVE

Mining and the African environment

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Abstract

Africa is on the verge of a mining boom. We review the environmental threats from African mining development, including habitat alteration, infrastructure expansion, human migration, bushmeat hunting, corruption, and weak governance. We illustrate these threats in Central Africa, which contains the vast Congo rainforest, and show that more than a quarter of 4,151 recorded mineral occurrences are concentrated in three regions of biological endemism—the Cameroon-Gabon Lowlands, Eastern DRC Lowlands, and Albertine Rift Mountains—and that most of these sites are currently unprotected. Threats are not uniform spatially, and much of the Congo Basin is devoid of mineral occurrences and may be spared from direct mining impacts. Some of the environmental impacts of African mining development could potentially be offset: mining set-asides could protect some wildlife habitats, whereas improving transportation networks could increase crop yields and spare land for conservation. Research and policy measures are needed to (1) understand the synergies between mining and other development activities, (2) improve environmental impact assessments, (3) devise mitigation and offsetting mechanisms, and (4) identify market choke points where lobbying can improve environmental practice. Without careful management, rapid mining expansion and its associated secondary effects will have severe impacts on African environments and biodiversity.

Introduction

Africa is on the verge of an unprecedented mining boom. This boom is attracting tens of billions of dollars in foreign investment (Janneh & Ping 2011; Zhang 2011) and will result in substantial economic growth and development, but it also carries big risks for African societies and the environment. Here we highlight potential environmental threats posed by the rapid escalation of large- and small-scale mining.

Africa contains around 30% of the world's mineral resources—including the largest known reserves of a wide range of strategically important minerals, including phosphate, platinum-group metals, gold, diamonds, chromite, cobalt, manganese, and vanadium, and huge deposits of aluminum, uranium, iron ore, and coal (Taylor *et al.* 2009). Yet with less than 5% of global mineral exploitation having occurred in Africa, and large parts of the continent being geologically unexplored, the potential for growth is enormous (Taylor *et al.* 2009).

Africa's mineral wealth is now attracting a stampede of foreign investment. Chinese investment in African mining quadrupled from 2000 to 2009, from US$25.7 billion to US$103.4 billion per year (Zhang 2011). While Chinese investment is skyrocketing, so too is investment from the other BRIC countries (Brazil, Russia, and India) and western countries (especially Canada and Australia), with investment growing equally fast in relative terms (Janneh & Ping 2011). For instance, more than 230 Australian mining companies are involved in over 600 projects in mining exploration, extraction, and processing across more than 42 African countries, with a total current and projected investment of more than US$45 billion (USGS 2011). Such investment is historically unprecedented in African natural resource development (Broadman 2007; Janneh & Ping 2011).

The upsurge in mineral exploration and exploitation is often linked to major infrastructural projects, including roads and railways to move commodities from mine to smelters, as well as shipping ports for export, and hydroelectric dams. In the Democratic Republic of Congo, for instance, Sicomines, a Sino-Congolese joint venture, obtained a world-class copper reserve, the Dikulwe-Mashamba concession (Putzel *et al.* 2011), and then invested US$9 billion in roads, railways, and other infrastructure with Chinese financial backing. Similarly, in Mozambique, the Brazilian mining company Vale is investing $4.4 billion in rebuilding the railway system from the northern coalmines to the city of Tete (Mining Weekly 2013).

This tsunami of mining and infrastructural investment is creating a new optimism in Africa about economic development and poverty alleviation, but it is also occurring in a complex socioeconomic context. Africa has a rapidly growing population, is the poorest continent overall, lacks a skilled workforce, and has significant political instability and corruption (Twerefou 2009). African countries certainly have concerns about these issues, but few have governance capacity to deal with the scale and speed of the present wave of investments. While the socioeconomic challenges surrounding mining are often great—as exemplified by a recent police massacre of 34 striking miners at the Marikana platinum mine in South Africa (Ramutsindela 2013)—we focus here primarily on the potential impacts of mining on nature conservation.

Potential negatives for conservation

Mining is going to have a *massive* influence on the natural environment in Africa, with the potential for impacts at any particular locale determined by the scale of operation and the infrastructure needed to extract and transport prospective minerals. This is a function of the type of mineral commodity: high-volume, low-value bulk minerals such as iron ore require larger and different infrastructure than do low-volume, high-value minerals such as diamonds and gold.

The negative impacts of mining are both direct and indirect. Direct effects occur within the immediate confines of the mining enterprise (Durán *et al.* 2013). Indirect effects are a consequence of external infrastructure, pollution, synergistic developments, and population migration. In terms of direct negative impacts on the natural environment, mines can directly remove, fragment, or degrade natural habitat, with the affected area ranging from <1 to several dozen km^2 in area, depending on the mineral being mined (Edwards 2001). A related concern is the specter of downgrading, downsizing, and degazettement of protected areas (PADDD) to allow mining prospecting and development. Across Africa, there have already been instances of PADDD for mining in at least five countries (Table 1). In the Republic of Guinea, for example, the Mount Nimba Biosphere Reserve, a World Heritage Site, was downsized by 1,550 ha to allow for iron-ore prospecting. Further, some 44% of Africa's major metal mines are inside or within 10 km of a protected area, considerably more than the 25% in both Asia and South America (Durán *et al.* 2013).

The immediate, relatively local environmental impacts of mining per se may be dwarfed by the potentially far more wide-ranging impacts of mining infrastructure and socioeconomic change. The expansion of roads and railways driven in part by extractive industries remains one of the biggest threats to natural habitats and wildlife populations (Blake *et al.* 2007; Laurance *et al.* 2009), and will increase access to some of the world's most biodiverse ecosystems, including the eastern Congo rainforests, the Miombo and Guinea woodlands, and the Rift valley savannas and mountains. In Gabon, for example, the Belinga iron-ore deposit sits deep within the Congo rainforest, and will require the construction of a 240-km railway line (Ash 2013). In Cameroon a 570-km railway will link the Mbalam iron ore mine with the Atlantic coast (Toledano 2012), whereas in Tanzania, a proposed road to the goldfields by Lake Victoria could bisect the Serengeti National Park and disrupt one of the world's greatest surviving terrestrial wildlife migrations (Dobson *et al.* 2010).

By creating and improving infrastructural networks, mining could have major impacts on the spatial patterns of rural development in Africa. Mining roads will certainly encourage major movements of populations into hitherto sparsely populated regions and this will increase pressures from land clearing and bushmeat hunting for local consumption (Wilkie & Carpenter 1999; Brashares *et al.* 2004). Further, as roads cut into previously inaccessible forests, they will pave the way for an influx of commercial bushmeat hunting to supply major urban centers and foreign labor (Wilkie & Carpenter 1999; Cowlishaw *et al.* 2005; van Vliet *et al.* 2012), and wildlife traders, who supply the international trade in pets, ivory, or medicinal products (Stiles 2011; Luiselli *et al.* 2012; Maisels *et al.* 2013). These are major extinction threats to many large-bodied mammals and traded species (Barnes 2002; Fa *et al.* 2005).

Extractive industries also attract a rush of migrant people from outside the mining areas in search of work

Table 1 Examples of Protected Area downgrading, downsizing, and degazettement (PADDD) for mining prospecting or extraction in Africa. Downgrading relates to a reduction in the level of legal protection, downsizing to a reduction in park area, and degazettement to a removal of formal protection. Source is PADDDtracker www.PADDDtracker.org (accessed Jan 2013)

Country	Location	PADDD	Year	Area km^2	Mining activity
Guinea	Mount Nimba World Heritage Site	downsize	1993	15.5	Iron-ore prospect
Zambia	19 National Parks	downgrade	1998	63,585	Mining
Uganda	Queen Elizabeth National Park	downgrade	2005	unknown	Limestone
DRC	Basse Kando Reserve	degazette	2006	unknown	Mining
South Africa	Marakele National Park	downgrade	2009	unknown	unknown
Tanzania	Selous Game Reserve	downsize	2012	200	Uranium

or to undertake small-scale artisanal mining outside the boundaries of the "official" mine. Artisanal miners are economically marginalized people using unregulated, improvised, and often harmful extraction methods to piggyback onto operations involving precious commodities, especially gold and diamonds. In some instances, populations in local towns or villages near major mines swell very rapidly. For instance, Geita township in Tanzania quadrupled in size within 3 years, from 30,000 residents in 1999 to 120,000 residents in 2002 (Lange 2006), following the opening of Geita Mine, Tanzania's largest open-pit gold mine. Such collateral development and immigration can have serious negative impacts on the environment. Local wildlife and forests are overexploited while local mining enterprises are often polluting, releasing toxic chemicals into rivers (Durand 2012), including mercury in the case of gold extraction. Combined with huge increases in sediment loads, mercury severely alters the species composition of aquatic communities (Brosse *et al.* 2011), and bio-accumulates in fish (Gammons *et al.* 2006) and ultimately humans (Banza *et al.* 2009; Yabe *et al.* 2010).

At larger spatial scales, there will also be synergies between these new transport networks and industrial-scale commercial agriculture, such as oil palm (Sayer *et al.* 2012b), which is rapidly developing in Africa (Fitzherbert *et al.* 2008). The development of plantation and crop monocultures at the expense of forest is the major driver of global declines in biodiversity across the tropics (Fitzherbert *et al.* 2008; Gibson *et al.* 2011), spanning the entire array of vertebrate and invertebrate taxa, including those already subjected to bushmeat hunting and wildlife trade. Expansion of intensive crop monocultures in forest locations opened by mining infrastructure development would thus cause major conservation losses and carbon release (Danielsen *et al*. 2008).

Finally, vast sums of money from mining and weak national governance result in widespread corruption. Many of the African nations in which mining and associated infrastructure are rapidly expanding rank very poorly on Transparency International's corruption perceptions index (Transparency International 2012). Of the 176 countries and territories evaluated worldwide, all six of the Central African countries that collectively encompass the vast Congo Basin rainforest fair very poorly: Cameroon, Central African Republic, and Republic of Congo were jointly ranked 144th; Democratic Republic of Congo, 160th; Equatorial Guinea, 163rd; and Gabon, 102nd. Further, many governments lack the capacity to implement adequate mining-development controls, particularly given the potential for civil unrest over access to valuable minerals such as diamonds, as evidenced by past conflicts in Angola, Sierra Leone, and Liberia. The potentially toxic mix of massive investment in mining, weak governance and enforcement capacity, corruption, and civil unrest—the so-called "Resource Curse" (Auty 1993)—mean that legal frameworks to protect environmental resources are frequently subverted or totally ignored in the pursuit of mining and self interest (Laurance 2004). Some instances of PADDD for mining in Africa (Table 1) are highly likely to have resulted from corruption (Mascia & Pailler 2011), illustrating that where corruption is rife, transparent and considered decision-making regarding natural habitat protection is extremely challenging.

Where are impacts likely to occur in Central Africa?

Identifying unexploited mineral reserves is a complex science and multibillion dollar industry (Edwards 2001), so we do not claim to be able to predict precisely where the next wave of mining and associated risks to the natural environment will occur. However, we can use known mineral occurrences to illustrate the potential scale of the issue. Central Africa includes the Congo Basin, the world's second-largest surviving rainforest, which sustains high biodiversity (Jetz & Rahbek 2002) and is inhabited by tens of millions of people who depend on

Table 2 Counts and percentages (in brackets) of mineral occurrences inside or within 10 km of Endemic Bird Areas (Birdlife International 2005) and Protected Areas (IUCN & UNEP 2010) of Central Africa

	EBAs		PAs		EBAs or PAs	
Total No. of Occurrences	*Inside*	*Inside or Within 10 km*	*Inside*	*Inside or Within 10 km*	*Inside*	*Inside or Within 10 km*
4151 (100)	1101 (26.5)	1188 (28.6)	430 (10.3)	964 (23.2)	1377 (33.2)	1721 (41.6)

Sources and Notes: Percentages are within brackets. Other sources and notes as per Figure 1.

forests for their livelihoods (Ndoye & Tieguhong 2004). The Central African region and adjoining areas to the South contain some of Africa's largest deposits of copper, cobalt, and coltan, and they have significant potential for coal, iron ore, aluminum, gold, and diamonds, among others (Reed & Miranda 2007; Taylor *et al.* 2009).

An analysis of the distribution of 4,151 mineral occurrences (Hammerbeck *et al*. 2008), spanning 21 commodity types (excluding coal), relative to centers of bird endemism (restricted-range species; Birdlife International 2005) and existing protected areas (IUCN & UNEP 2010) (see Text S1 for Methods), indicates that the complete development of Central Africa's mineral resources would directly impact a third of these ecologically important locations (Table 2, Figure 1). This rises to 42% if one assumes that ecological impacts will extend 10 km from the footprint of individual mines. Nearly one-third of all active mines and exploration sites are located within intact ecosystems of high conservation value, with almost one-third of all active mines located in stressed watersheds (Reed & Miranda 2007). At present, only 3.8% of major metal mines (aluminum, copper, bauxite, and zinc) occur inside African protected areas (Durán *et al.* 2013), but this figure would rise to 10.3% (430 mines within 103 protected areas) if all known mineral occurrences were developed in Central Africa (Table 2). The total number is almost certainly somewhere in between these values. Of the known occurrences, ∼55% are gold and diamonds, which are predominantly exploited by small-scale artisanal miners.

Most threatened by far, however, are ecologically important forests that are currently unprotected. More than one-quarter (1,101) of Central African mineral occurrences are concentrated in three key regions of high biological endemism—the Cameroon-Gabon Lowlands, the Eastern DRC Lowlands, and the Albertine Rift Mountains (Birdlife International 2005)—each of which contains some of Africa's most iconic protected areas (Figure 1). However, of the 1,377 reported mineral occurrences in either high-endemism areas or protected areas, only 154 are common to both; the bulk are in unprotected high-endemism areas (Figure 1, Table 2). As such, safeguarding protected areas from mineral exploitation alone would do little to shield endemic biodiversity from mineral exploitation in Central Africa. If biodiversity is to be protected during the coming mining boom, as many as one-quarter of all mines may require special measures to conserve globally important biodiversity that would be impacted by mining development (again, liberally assuming that all mineral occurrences are actually developed into mines).

The observed colocation of mineral occurrences with centers of biological endemism is unlikely to be unique to Central Africa, and can be attributed to an interplay between underlying geology and tectonic processes that expose isolated and unique geological formations at the land's surface across Africa (e.g., Roberts *et al.* 2012), driving the evolution of unique flora and faunas (e.g., Jetz & Rahbek 2002; Schwarzer *et al.* 2009). This highlights the need to look beyond protected areas toward hotspots of biological endemism across Africa, and to proactively plan (or restrict) mining development at regional, rather than local, scales.

Our spatial analysis of mineral occurrences does reveal some positives. In particular, a great expanse of contiguous rainforest in the Congo Basin may be spared the direct effects of mining. These densely forested lowlands are underlain by sedimentary formations largely devoid of known mineral occurrences (Figure 1). These forests are likely to be vulnerable, nonetheless, to indirect effects arising from the development of transport corridors intended to move mineral and industrial-agricultural commodities across national borders and to port (Limão & Venables 2001; Faye *et al.* 2004; Weng *et al.* 2013). For instance, three planned development corridors, termed the Northern Corridor, Central Corridor, and Lobito Development Corridor, would link the Democratic Republic of Congo and other Central African countries with their southwestern and eastern neighbors, via expanded cross-border road and rail lines (Weng *et al.* 2013). These transport corridors would bisect major wilderness areas and threaten several renowned World Heritage Areas,

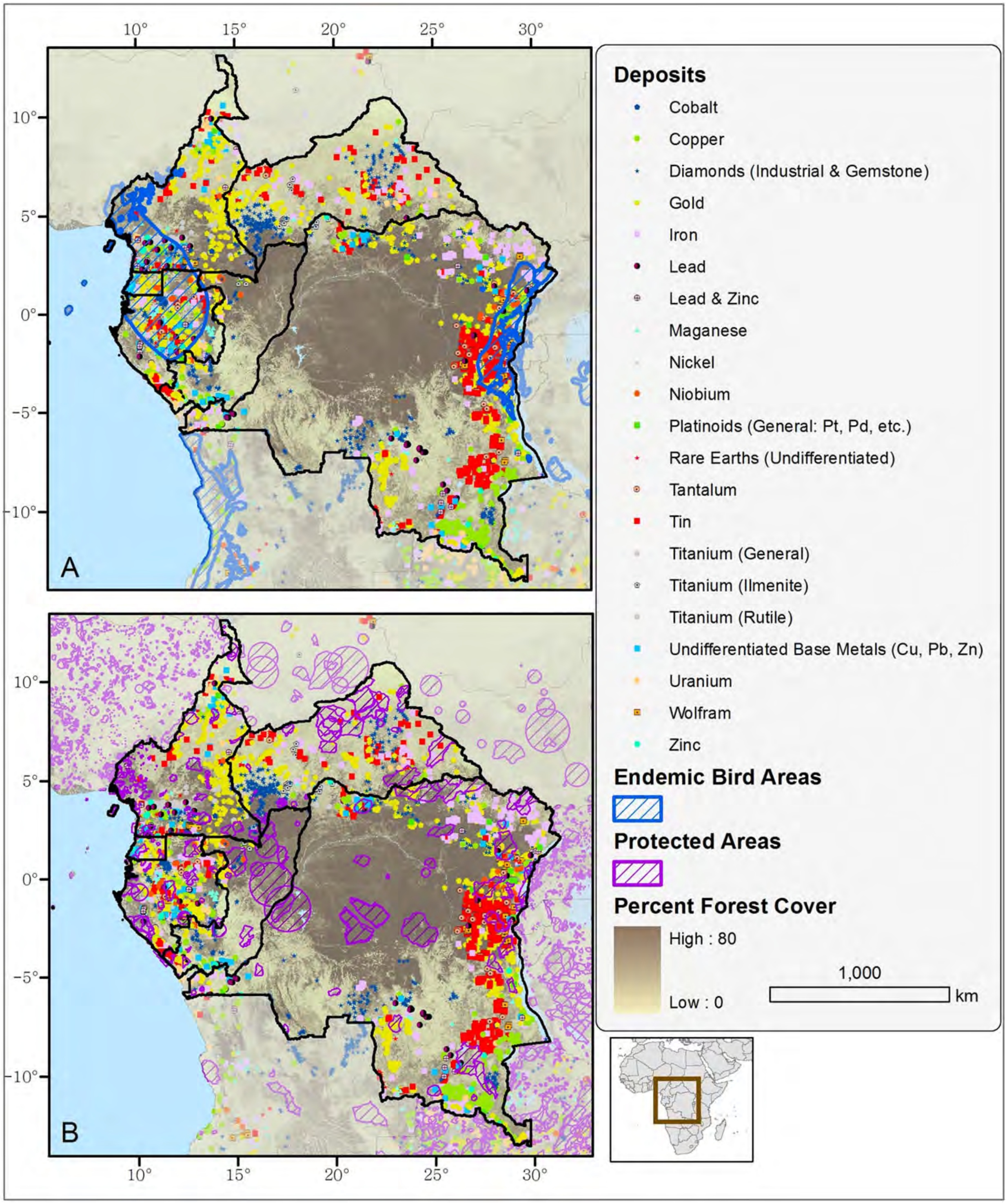

Figure 1 Distribution of mineral occurrences in Central Africa relative to (A) Endemic Bird Areas and (B) Protected Areas (PAs). Not all mineral occurrences are being actively exploited, and many are under "artisanal" exploitation only. PAs not delineated by the WDPA are mapped as circles centered on PA coordinates, where circle area is proportional to PA area (IUCN & UNEP 2010). Percent forest cover is based on a MODIS satellite composite for 2010–2011 (Townshead *et al.* 2011).

including the Ituri "Okapi" Forest and the Virunga, Kahusi-Biega, and Maiko National Parks.

Potential positives for conservation

It is overly simplistic to portray the likely impacts of mining as entirely negative. In some instances, mining operations have effectively created conservation zones and, as such, offset some of their negative impacts. Several large-scale mining projects, such as the Mbalam iron-ore mine adjacent to the Dja World Heritage site in Cameroon, now include provision for biodiversity set-asides, which would protect rare forest mammals (Reed & Miranda 2007). Elsewhere in Africa, the Sperrgebiet area in southwest Namibia, an arid hotspot of biodiversity, was completely off-limits to local resource extractors because of claims on alluvial diamond deposits, and has since been designated as a protected area. Such set-asides and exclusion zones, if well managed, may help to balance resource extraction with conservation, particularly in endemic-rich locales that lack formal protection.

Among development agencies, conventional wisdom in recent years has been that foreign direct investment is essential to grow African economies and alleviate poverty (Broadman 2007). Some have argued that it is easier to achieve positive environmental outcomes in situations of growing economies (Sayer *et al.* 2012a). Mining certainly affords large foreign and domestic investment, with billions of dollars of mining revenues and royalties already flowing to African governments (Stürmer 2008, 2010) and with the prospect for some poverty alleviation (assuming that mining proceeds do not simply end up enriching social and economic elites, or driving major economic inflation; Auty 1993). If mining investment could be achieved in situations of strong governance allowing for biodiversity protection, ecosystem services, and sustainability concerns, then there could potentially be win-wins for society and conservation (Sachs *et al.* 2009; Sayer *et al.* 2012b). Unfortunately, when mining encourages corruption and weakens national governance, both social and environmental goals suffer (Smith *et al.* 2003; Laurance 2004).

Mining has the potential to drive development processes in ways that might contribute to nature conservation. Most of Africa's agriculture is relatively unproductive and vast areas are exploited for meager returns. Improved transport networks promoted by mining could increase small farmers' access to chemical fertilizers and reduce transport costs and wastage, improving farm profitability (Faye *et al.* 2004; Gajigo & Lukoma 2011). Under this scenario, Africa's food production could rise significantly without a major expansion of the area under cultivation, to the benefit of biodiversity (Edwards *et al.* 2010; Phalan *et al.* 2011). These positive conservation outcomes will only occur with effective land-use zoning (Balmford *et al.* 2012) and by limiting road expansion in environmentally sensitive areas (Laurance & Balmford 2013). A less optimistic scenario is that new transport infrastructure could encourage expansion of larger-scale industrial land conversion (Weng *et al.* 2013) and displace resident populations, whose land rights are not legalized, into areas of natural habitats. The agricultural footprint of Africa's many smallholders could thus continue to expand (Lambin & Meyfroidt 2011).

At the smallest scale, recent attention has focused on low-income artisanal miners, many of whom earn a significant part of their total income by mining gold, coltran and diamonds (often earning no more than US$3.1 per day; Chupezi *et al.* 2009), but who collectively can have serious negative environmental impacts. Considerable research is now being focused on reducing mercury pollution while improving the environmental management of artisanal mining, via training, microfinance and fairer gold-marketing arrangements (Spiegel 2009; Hilson & Ackah-Baidoo 2011; Sippl & Selin 2012), but again this will only occur if corruption is reduced and national governance and enforcement capacity improved.

Critical directions

Given the dramatic magnitude of the African mining boom, we highlight four key challenges and mechanisms on which conservation scientists can valuably focus their attention:

(1) Traditionally, industrial mining in Africa was controlled by western companies with neo-colonial attitudes and a capitalist, market-driven approach to extraction, with much of the profit made offshore and a narrow focus on the mine site. By contrast, Chinese and Brazilian operators appear to be taking a strategically much broader approach, offering soft loans, development-assistance packages, and infrastructure development, in return for mining or exploration rights (Carmody 2011; Moyo 2012). For instance, the Brazilian sponsored Tete Development corridor in Mozambique integrates mining and agricultural development (Robbins & Perkins 2012). Understanding the nature of these two business models and their synergies with other development activities is vital to predicting and mitigating the implications of mining for the African environment.

(2) Most large mining companies conduct an Environmental Impact Assessment (EIA) and related social studies, and should apply strict mitigation controls

within the confines of the mine. However, government control and enforcement of EIAs is often weak or totally absent, and particularly so in Central Africa, allowing mining companies to conduct substandard assessments, to fail to apply appropriate mitigation, and even not to bother with the EIA process at all. EIAs are necessary for stock exchange listings (International Organization for Standardization ISO14001 compliance [ISO]) and to obtain funding from the International Finance Corporation (IFC), which is part of the World Bank Group (IFC 2013). IFC loans encourage commercial investors who apply the Equator Principles, which impose high governance and environmental standards, while ISO stock-certification schemes require social and environmental safeguard measures. The Extractive Industries Transparency Initiative (EITI 2013) also shows promise of combating the corrupting influence of mineral industries. It is under these international frameworks that we foresee leverage in promoting and obtaining adequate safeguards to ensure that EIAs are of "international" quality, that mitigations are appropriate and are adhered to, and that they are coupled with enforcement via fines or capital withholding. Obtaining a within-mine EIA framework of international standard is thus the immediate key challenge.

However, even international-standard EIA processes usually ignore or underestimate the multitude of secondary effects of mine development, especially those on broader development patterns (Laurance 2008; Weng *et al.* 2013). Mining companies are reluctant to engage in debate on their off-site impacts. Companies argue that their liability ends at the mine gates and endures only for the lifetime of the mine. They argue that governments have the role of addressing macro-level environmental, economic and social impacts. However, in many African countries the governmental institutions responsible for assessing these external impacts are weak and lack the capacity to deal with negative impacts. Conservation scientists therefore need to engage more effectively with governments but also with the IFC, Equator Principles, and ISO to expand the focus of environmental and social safeguards to these broader development impacts.

More generally, there is a need for higher-level, strategic environmental assessments applied at regional and national levels. In the context of any mining boom, piecemeal EIAs conducted on a per-mine basis are unlikely to capture the cumulative regional environmental effects, nor mitigate them (Laurance 2008). We advocate strategic assessments within the context of national and regional development processes, encompassing conservation targets but also goals for mining, transport, employment, and agriculture.

(3) Conservation scientists need to engage in the creation of mitigation and offsetting mechanisms that are fit for purpose (Bekessey *et al.* 2010; Pilgrim *et al.* 2013). We advocate the development of offset mechanisms, perhaps by paying into a biodiversity land bank, such as a national protected-area trust fund, that protects key habitats close to the mine or similar habitat elsewhere, or by paying to help safeguard existing protected areas that are currently suffering from encroachment (Blom 2004; Laurance *et al.* 2012). Such offset payments would need to be deposits made early on in the mine-development process as a condition of a license. Understanding the ratio between damage caused by mining and the level of payments made requires urgent attention.

(4) In (2) and (3) we highlight specific activities for identifying and mitigating the negative environmental impacts of mining. However, a key concern is how to ensure the uptake of these activities by a mining sector that it frequently under weak governmental control. A similar challenge has been raised by the expansion of plantation agriculture in the tropics (Gibbs *et al.* 2010), but the development of agricultural sustainability labels is providing some economic traction to promote better practices (Edwards & Laurance 2012; Edwards *et al.* 2012). Pivotally, these labels have been coupled with pressure applied at key "choke points" in the market chain where lobbying, publicity and even consumer boycotts have helped to ensure participation throughout the commodity chain.

We need to understand far more effectively where the market choke points are in the mining sector. For instance, there are only five major stock exchanges where the vast majority of mining prospectors (so-called "Juniors") sell their prospects to the large corporations ("Majors") that control the mining assets. Conservation scientists might focus on these stock exchanges as leverage points for improving environmental standards across the industry. An additional positive is that such market choke points are likely external to Africa, making them less corruptible and open to wider scrutiny by a range of stakeholders. While market choke points are perhaps the most likely mechanism to drive change, they are not a panacea. Other players in the African mining sector, particularly the African *nouveau riche* and Chinese interests, are likely to have very different, perhaps even nonmarket choke points (including stable relationships with African governments and the integrity of integrated development plans). Some minerals, such as coltran, are traded outside of stock exchanges, with direct agreements between buyer and seller, and leveraging needed changes for such minerals may also prove more challenging.

Conclusions

Africa is experiencing a remarkable mining boom, largely driven by foreign investment. The speed and scale of this development means that environmental considerations are in danger of being marginalized or even totally ignored, and thus that some of Africa's most valuable biological real estate, including the rainforests of central Africa, is in grave danger. At present, attention is focused on the local impacts of mine-site operations, but we argue that far greater threats and potential conservation opportunities revolve around infrastructure expansion, bushmeat and wildlife trade, human migration, governance, and macro-economic changes associated with mining development. Mining is undoubtedly going to alter the face of Africa over the coming decades. Opportunities for sustainable development, poverty alleviation, and improved environmental protection exist, but such positive outcomes will rarely be achieved under current conditions of corruption and weak governance. Business-as-usual practice carries with it a danger that explosive mining development could accelerate the loss of Africa's forests and natural areas with consequent losses of biodiversity. Initiatives such as the Extractive Industries Transparency Initiative (Weng *et al*. 2013) and a number of bilateral, mining-for-development programs (AusAID 2011) show promise and might help to reduce the threats posed by mining while increasing opportunities for sustainable development.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Text S1: Methods for overlaying Central African mineral occurrences with EBAs and PAs

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