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The secondary impact of mining on primates and other medium to large mammals in forest reserves in southwestern Ghana

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ABSTRACT

The upsurge of mining in Africa promises substantial economic development opportunities, but poses serious threats to the continent's natural environment and rich biodiversity. We assessed the impact of mining on medium to large mammals in the Western Region of Ghana. We surveyed mammals in the project area and two forest reserves (FRs) before the commencement of mining operations and 10 years after mine closure and forest rehabilitation. The methodology involved direct and indirect observations along transects as well as focus group discussions. We found declines in species diversity of primates and other medium to large mammals in the core mining areas and within FRs. Forest rehabilitation after mine closure did not allow recovery of mammals in the core areas to previous levels in the FRs, as potential sources of colonisers from the FRs were removed. The discussants consumed bushmeat regularly, and agreed that mammal diversity in the area had declined due to noise from mining operations and hunting within FRs. Our data suggest that mining impacted negatively on medium to large mammal diversity. Greater management effort is needed to regulate hunting in forest reserves adjoining mining areas to avoid extirpation of primates and other wildlife species from Ghana's rainforest.

1. Introduction

Globally, natural ecosystems have been destroyed or degraded with increasing human impact and land-use changes (Butchart et al., 2010). Anthropogenic influences like mining, intensification of agriculture and forestry, large-scale industrialization, unsustainable hunting, invasive species and climate change have led to population declines and species level extinctions (Pimm and Raven, 2000; Pimm et al., 2006; Brook et al., 2008; Krauss et al., 2010). Increasing concern over human-induced environmental degradation and biodiversity loss has elicited international, regional and local responses to protect the natural environment and conserve biodiversity. At the global scale, the Convention on Biodiversity (CBD) aims at safeguarding biodiversity and ecosystem services (Kullberg and Moilanen, 2014). In 2002, the CBD mandated its member states to institute strategies to reduce environmental degradation and the rate of biodiversity loss dramatically by 2010 (COP 6 Decision VI/26).

In line with the CBD (2002) directive, member states developed biodiversity action plans and strategies, including the establishment of protected areas (PAs) to conserve biodiversity and the natural environment (Watson et al., 2014). Although PAs have been around for millennia (Chape et al., 2005), their number and extent have increased dramatically in the past few decades. Currently, terrestrial PAs cover about 12.5% of the earth's surface, with almost every country in the world having some form of legally-designated national protected area (Geldmann et al., 2013; Watson et al., 2014). The Strategic Plan for Biodiversity and the Aichi Biodiversity Targets (http://www.cbd.int/decision/cop) recognize PAs as cornerstones and mainstays of *in situ* biodiversity conservation, calling for an increase in the coverage of global PAs to at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas by 2020 (Target 11).

Although increasing the number and/or size of PAs is laudable and must continue, the physical extent of PAs is not a measure of their effectiveness (Rodrigues et al., 2004; Chape et al., 2005), as they may fail to achieve their goals if the surrounding landscape matrix is poorly managed (Beaumont and Duursma, 2012; Gray et al., 2016). Protected areas are integral parts of larger ecosystems and therefore depend on adjoining landscapes to maintain the flow of matter and energy (DeFries et al., 2005; Gray et al., 2016). The effectiveness of PAs in conserving biodiversity can be strongly influenced by land use practices and changes in the surrounding landscapes (Laurance, 2012; León-Ortega et al., 2017). The ever-increasing human populations and standard of living, as well as demand for multiple ecosystem services in developing tropical countries have intensified the scramble for lands

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surrounding PAs (Newmark, 2008). Fragmentation of landscapes adjacent to PAs can lead to increased exposure of PAs to negative human impacts (Beaumont and Duursma, 2012).

The booming mining industry in Africa presents enormous economic growth and development opportunities as extraction and processing of minerals provide important sources of employment and wealth creation (Hilson, 2014; Virah-Sawmy et al., 2014). However, mining poses serious risks to the continent's natural environment and exceptionally rich biodiversity (Yelpaala and Ali, 2005; Deikumah et al., 2014; Abernethy et al., 2016; Attuquayefio et al., 2017). The negative impacts of mining on the environment and biodiversity may be direct or indirect. Direct negative impacts include habitat loss and fragmentation, killing of wildlife during land clearance, disruption of hydrological systems and air and water pollution within and beyond the immediate confines of the mining operations (Durán et al., 2013). The indirect impacts of mining result from the consequences of mining infrastructure and associated socioeconomic changes (Osti et al., 2011; Abernethy et al., 2016).

PAs are supposedly spared from mining activities, but when they coincide with mineral deposits, they may be downgraded, downsized or degazetted (PADDD), to allow mining prospecting and development (Edwards et al., 2014). This is a worrying phenomenon, particularly in Africa, where most PAs harbour mineral resources (Abernethy et al., 2016) and about 44% of major mining sites are situated inside or within a few kilometres outside PAs (Durán et al., 2013).

By creating and improving infrastructure networks, mining can strongly influence the economy and demography of mining communities (Virah-Sawmy et al., 2014), which are often rural and sparsely populated (Edwards et al., 2014). Mining operations and infrastructure may encourage and facilitate migration of people into mining areas in search of mining-related jobs or to undertake small-scale artisanal mining outside the boundaries of the "official mine". This rapidly increases the populations and pressure from land clearing and bushmeat hunting for local consumption (Edwards et al., 2014; Abernethy et al., 2016). Roads may constructed through hitherto inaccessible forests and PAs, creating an influx of commercial bushmeat hunters and illegal loggers (Espinosa et al., 2014; Laurance et al., 2017). Also, local people displaced from their lands by mining activities may encroach on protected forests in their quest for economic spaces, threatening wildlife and their habitats in the process.

The conflict between economic benefits of mining and conservation initiatives is becoming increasingly acute. This is particularly evident in developing countries, where the material needs of an ever-increasing population compete with diminishing tropical rainforests (Fiori and Zalba, 2003; Suarez et al., 2009; Durán et al., 2013). Mining and associated infrastructural development promise economic opportunities that seem too good to part with, even when it imperils irreplaceable ecosystems. The expansion of mining industries in developing tropical countries has failed to provide the expected and much-needed development (Hilson, 2014). Indeed, the exploitation of mineral and oil resources has impacted negatively on the economy and governance outcomes of many developing countries (Busse and Gröning, 2013; Corrigan, 2014). This "resource curse" is believed to be due to host governments' inability to manage the sudden influxes of revenue from mineral exploitation (Mehlum et al., 2006; Robinson et al., 2006; Boschini et al., 2007; Collier, 2008; Corrigan, 2014; Hilson, 2014). This coupled with corruption has exacerbated pre-existing societal inequalities, nepotism and social injustice, thereby perpetuating conflicts, political instability and despotic governments in many developing countries (Bhattacharyya and Hodler, 2010; Corrigan, 2014; Hilson, 2014; Kelly, 2014). It is however worth acknowledging that some developing countries endowed with huge mineral resources are performing very well in terms of economic development and quality of governance (Corrigan, 2014).

The need for economic growth and improved living standards of ever-growing human populations in developing countries and the magnitude of global rise in demand for mineral resources mean that plans for large scale mining will continue unabated in developing tropical countries. Given the environmental concerns of mining, it can be expected that operators will increasingly be required to reduce their levels of environmental impacts. A number of environmental assessment tools and methodologies have been developed by the international community to help mitigate the negative impacts of mining on biodiversity and the natural environment (Norgate et al., 2007). Among these are environmental impact assessment (EIA) and biodiversity offsets. The EIA is a legal requirement prior to mining operations, and characterizes the potential impacts of mining projects on the environment. This results of the EIA is used to prepare an environmental impact statement (EIS), which stipulates measures to be implemented to reduce or offset the potential negative effects of mining (Morgan, 1998; Attuquayefio et al., 2017). The basic approach of biodiversity offset is to quantify biodiversity loss caused by mining projects, which occur even after implementation of impact mitigation measures, and then to generate biodiversity benefits through compensatory activities that offset the impacts (Maron et al., 2012; Bull et al., 2013a; Gardner et al., 2013). Biodiversity offset schemes generally aim to achieve an overall no net loss of biodiversity (McKenney and Kiesecker, 2010; Bull et al., 2013b). Although the secondary impacts of mining may have far-reaching ramifications for local and regional biodiversity, these are rarely addressed in EIA and biodiversity offset processes.

The rainforest of Ghana harbours a spectacular diversity of plants and animals, provide myriad of natural products and services to local communities, and plays key roles in the hydrological cycle, as well as being rich in gold and other precious minerals (Akabzaa, 2000; Rajaee et al., 2015). Unfortunately, the country's rainforest is being degraded and fragmented by large-scale land-use change and other environmental alterations (Damnyag et al., 2012; Hackman and Gong, 2017). Mining in Ghana's rainforest poses enormous risks to the nation's biodiversity and natural environment with large tracts of intact forest being cleared, topsoil removed and mine waste dumped into water bodies (Hilson and Nyame, 2006; Schueler et al., 2011). In many areas, loggers, migrant workers and commercial hunters attracted by the mines further stress the forest resources by poaching wild animals (normally medium to large mammals and birds) for bushmeat (Ntiamoa-Baidu, 1998; Ofori and Attuquayefio, 2010).

In 1996, we conducted a baseline survey as a basis for an Environmental Impact Assessment (EIA) for a proposed development of an open-pit gold mine, ore processing plant and associated infrastructure at Damang, near Tarkwa in the Western region of Ghana. We surveyed medium to large mammals in the proposed mining operation areas and two adjoining forest reserves (FRs). As part of mitigation efforts, the mining company initiated forest regeneration and rehabilitation programmes after mine closure. To assess the effect of mining on medium to large mammals and the success or otherwise of the reclamation and forest regeneration initiative, we conducted a second survey in the mining area and the two FRs previously surveyed in 2007 after mine closure and forest rehabilitation. To enable comparison of results, we followed the same protocols used in the baseline study. We hypothesized that abundance and species richness of medium to large mammal species will decline in the mining area and adjoining forest reserves due to direct and indirect impacts of mining in the core mining area and FRs, respectively. We also expect mammal community composition in the core mining area and FRs to change due to influx of disturbance-tolerant species in the core mining area and loss of hunting sensitive species from FRs as local hunters direct hunting expeditions toward the FRs.

2. Materials and methods

2.1. Study area and sites

The study area in the Western Region of Ghana (Fig. 1) has been