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Global spatial coincidence between protected areas and metal mining activities

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ABSTRACT

The global protected area (PA) system has a key role to play in biological conservation, and it is thus vital to understand the factors that are likely to limit this potential. Attention to date has focused foremost on the consequences of biases in the spatial distribution of PAs for their effectiveness and efficiency in representing biodiversity. What is less clear is the extent to which these biases may also have affected the likelihood with which PAs coincide with or are influenced by particular kinds of threatening processes, further undermining their role. An obvious candidate for such concerns is metal mining activities. Here we demonstrate that approximately 7% of mines for four key metals directly overlap with PAs and a further 27% lie within 10 km of a PA boundary. Moreover, those PAs with mining activity within their boundaries constitute around 6% of the total areal coverage of the global terrestrial PA system, and those with mining activity within or up to 10 km from their boundary constitute nearly 14% of the total area. Given the distances over which mining activities can have influences, the persistence of their effects (often long after actual operations have closed down), and the rapidly growing demand for metals, there is an urgent need to limit or mitigate such conflicts.

1. Introduction

Terrestrial protected areas (PAs) are widely regarded as key elements of in situ conservation strategies at local, regional and global scales (Gaston et al., 2008; Margules and Pressey, 2000; MA, 2005). This reflects evidence of their historical success, when compared with areas that are not so protected, in holding significant components of biodiversity within their bounds (Andam et al., 2008; Gaston et al., 2008; Jackson and Gaston, 2008), and in buffering those components from external pressures (Chape et al., 2005). Nonetheless, numerous ways have been identified in which PAs could be improved, including individually in terms of their structure and management (Lockwood et al., 2006) and collectively in terms of their distribution and extent (Brooks et al., 2004; Fuller et al., 2010; Rodrigues et al., 2004). Particular attention has been focused on the frequent tendency for PAs to be biased towards lands at higher elevations, with steeper slopes, lower primary productivity, and/or lower economic worth (Hoekstra et al., 2005; Joppa and Pfaff, 2009). In other words, the tendency for PAs to be designated and established in parts of the landscape in which many (although not necessarily all) potentially competing uses are a priori minimized.

Such existing spatial biases in the distribution of terrestrial PAs are well known to have had important consequences. In particular, they have, often markedly, reduced their effectiveness and efficiency in representing biodiversity (Barr et al., 2011; Chape et al., 2005; Gorenflo and Brandon, 2006; Rodrigues et al., 2004). What is less clear is the extent to which these biases may also have affected the likelihood with which PAs coincide with or are influenced by particular kinds of threatening processes, yet further undermining their role. One obvious candidate for such concerns is metal mining activities, due to their location and environmental impact. For some key metals a high proportion of potentially accessible ore deposits tends, like protected areas, also to be located in topographically more complex areas and at higher altitudes (e.g. Edwards and Atkinson, 1986; Evans, 1993). Moreover, increasing demand (Fig. 1a) and prices (Fig. A.1) are extending these activities into more remote and previously unmined regions (Pulgar-Vidal et al., 2010). Consequently, metal mining activities have become of major export significance to several countries with notably high biodiversity (e.g. Chile, Peru, Zambia, Papua New Guinea; MA, 2005). Indeed, mining activities have proven a threat to a number of PAs, and such proposed activities are one driver of the downgrading, downsizing, and degazettement of PAs (Earthworks and Oxfam America, 2004; Farrington, 2005; Mascia and Pailler, 2011; Phillips, 2001).

Metal mining activities are potentially of major concern for biological conservation because they can be extensive and physically destructive of natural habitats, require infrastructure (e.g. for

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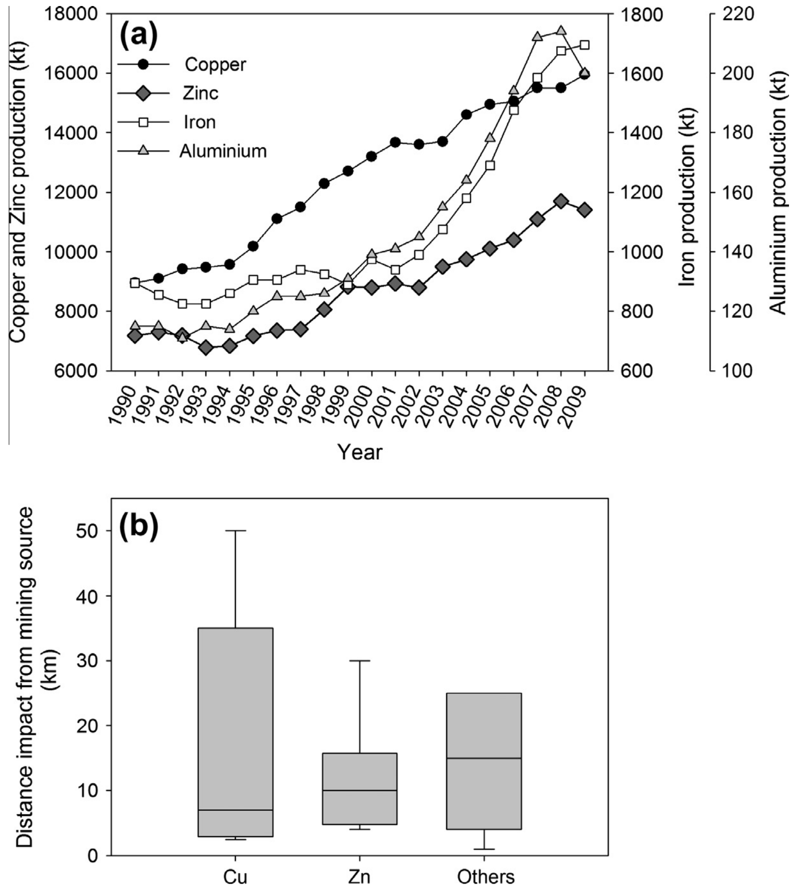

Fig. 1. (A) Annual variation in global production of aluminium, copper, zinc and iron from 1992 to 2010. (Information source: Raw Material Group). (B) Average maximum distance of ecological impacts from mining sources for three different mine types: copper, zinc and others. Fifteen papers that evaluate mining activity impact zones were reviewed (Table 2). Boxes show the median, upper value, lower value, 25th and 75th percentile.

transport) that can extend over yet larger areas (e.g. access roads, rail networks), and can cause both chronic and acute pollution that can persist for many decades (Lefcort et al., 2010). Moreover, this pollution can extend considerable distances from the mine workings themselves, with a new collation of the results of a set of published empirical studies showing effects on the scale of tens of kilometers (Fig. 1b). This raises the potential for PAs to be influenced by metal mine workings that lie well beyond their immediate boundaries.

In this paper, we determine the spatial overlap between terrestrial PAs and mining activities for ore deposits for four metals (aluminium (Al), copper (Cu), iron (Fe) and zinc (Zn)). We determine the variation across the globe both in direct overlaps and in the proximity of mining activities to the boundaries of PAs, which given the 'long reach' of these activities may be just as significant as is the occurrence of active mine workings within PAs.

2. Data and methods

Global maps of the locations of bauxite (for production of Al), Cu, Fe and Zn mines were developed using Rauch (2009) as the baseline dataset. This was updated using information on mining activities obtained from the Raw Material Group (RMG), the world's most extensive mining industry database, containing information on a broad range of legal mining industry entities. The latitude and longitude of mines were determined using company reports, company websites and other available sources. Every updated location was verified using images from Google Earth. The final dataset comprised information on a total of 1418 mines.

Data on the global distribution of PAs were obtained from the World Database on Protected Areas (WDPA, 2010). These data comprise both polygons and point records with associated extents. Following Rodrigues et al. (2004), (i) records were eliminated for marine PAs, and for PAs for which *Status* was indicated as "Proposed", "Recommended" or "Not reported"; (ii) point records were converted into circles of the stated area; (iii) point record circular areas were subsequently merged with those for which original polygon data were provided to generate a common polygon shapefile with a total of 129,422 records; and (iv) for the purposes of overlap analysis, but not for counting numbers and areas of PAs, the polygons that shared a common boundary or overlapped were dissolved. The IUCN Management category in which each PA has been placed was recorded (I – Strict Nature Reserve/Wilderness Area; II – National Park; III – Natural Monument or Feature; IV – Habitat/Species Management Area; V – Protected Landscape; VI – Protected area with sustainable use of natural resources; IUCN, 1994).

To determine the proximity of mines to PAs we overlapped the point locality data for mines and the final merged polygon data for PAs. Those mines that were located within PAs, or within distances of 1 km, 1–5 km and 5–10 km from the boundary of the PAs were accounted. We selected a maximum buffer distance of 10 km to capture potential local to mesoscale effects of mining activities on PAs, whilst acknowledging that longer distance effects can also exist. The coincidence of mine activity within PAs or the buffer distances defined (1 km, 1–5 km and 5–10 km) were compared with a null model in which the same numbers of mines as observed were randomly distributed across the global land masses (including