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Interactions between protected areas and their surroundings in human-dominated tropical landscapes

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ABSTRACT

Protected areas (PAs) often depend on landscapes surrounding them to maintain flows of organisms, water, nutrients, and energy. Park managers have little authority over the surrounding landscape although land use change and infrastructure development can have major impacts on the integrity of a PA. The need for scientifically-based regional-scale land use planning around protected areas is acute in human-dominated landscapes to balance conservation goals with livelihood needs for fuelwood, fodder, and other ecosystem services. As a first step, we propose the designation of a "zone of interaction" (ZOI) around PAs that encompasses hydrologic, ecological, and socioeconomic interactions between a PA and the surrounding landscape. We illustrate the concept by delineating the ZOI in three Indian PAs – Kanha, Ranthambore, and Nagarahole – using remote sensing, population census, and field data. The ZOI in Ranthambore is three times the size of the park and is largely defined by the socioeconomic interactions with surrounding villages. Ranthambore is located in headwaters and wildlife corridors are largely severed. In Nagarahole, the ZOI is more than seven times larger than the park and includes upstream watershed and elephant corridors. Kanha's ZOI is approximately four times larger than the park and is mostly defined by contiguous surrounding forest. The three examples highlight the differing extents of ZOIs when applying equivalent criteria, even though all are located in densely-populated landscapes. Quantitative understanding of which activities (e.g. collection of forest products, grazing, road construction, tourism development) and which locations within the ZOI are most crucial to conservation goals will enable improved land use planning around PAs in human-dominated landscapes.

1. Introduction

Protected areas are embedded within ecosystems that extend beyond their administrative boundaries. Only a few parks were designated based on ecological considerations of the larger landscape, notably Yellowstone National Park whose boundaries were intended to encompass the range of the grizzly bear (Craighead, 1979) and Serengeti-Mara Ecosystem whose boundaries were intended to encompass wildebeest migration routes (Thirgood et al., 2004). The boundaries of most protected areas were not designed to encompass the flows of water, energy, nutrients, and organisms across the landscape. Rather, protected areas are often located in lands less suitable for human use or areas of scenic value (Scott et al., 2001a,b).

The notion that interactions occur at scales larger than a protected area's administrative boundaries has led to calls for ecosystem management at regional scales (Grumbine, 1994; Liu and Taylor, 2002; Schneider et al., 2002). Land use change, dams, and a myriad of other anthropogenic forces outside protected area (PA) boundaries potentially affect ecological processes within, such as movements of organisms, fire and other disturbance regimes, and water availability. Case studies indicate the reduction or loss of many species in protected areas from habitat loss, hunting, disease and other factors (see Table 2 in Gaston et al. (2008)). These losses threaten to negate the progress in bringing additional areas under protected status in the last few decades (Naughton-Treves et al., 2005).

Park managers have little influence on decisions outside of a protected area's administrative boundaries. Moreover, the knowledge base is often incomplete to foresee the effect of anthropogenic activities on protected areas and the organisms residing within them. It is impractical and unrealistic to curtail all anthropogenic activities around protected areas. The scientific imperative is to identify which activities in which locations are most detrimental, as well as what opportunities exist to satisfy land use needs with minimal harm to ecological functions. For example,

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Gude et al. (2007) identify the opportunity to cluster new rural homes near towns and away from riparian habitat, elk winter range, and migration corridors in the Greater Yellowstone Ecosystem. The shift in location of new homes protects crucial habitat without reducing the number of homes, an example of a "small loss-big gain" opportunity (DeFries et al., 2004). Another example is China's Wolong Reserve, where provision of hydroelectric energy reduced local demand for fuelwood and improved panda habitat (He et al., 2009).

Satellite analyses indicate that land use change is occurring in lands surrounding protected areas throughout the world, particularly the tropics (DeFries et al., 2005; Joppa et al., 2008). We assert that the first step towards maintaining integrity of protected areas in the face of land use change is to designate a "zone of interaction" around the PA (Fig. 1). The zone of interaction (ZOI) delineates the surrounding landscape with strong hydrologic, ecologic, and socioeconomic interactions between PAs and their surroundings (DeFries et al., 2009). Based on this understanding, scientific input to regional-scale, ecosystem-based land use planning becomes a foreseeable goal.

The concept of a "zone of interaction" for protected areas in human-dominated landscapes expands upon the previously applied concept of a buffer zone. The latter has its roots in the Man and the Biosphere Program under the United Nations Educational, Scientific, and Cultural Organization in the early 1970s. The buffer zone model includes a core reserve surrounded by nested buffer zones with more intensive land uses with distance from the core (Heinen and Mehta, 2000). In practice, there is little agreement on whether the primary objective of buffer zones is to improve conservation in protected areas or to ameliorate the negative impacts of protected areas on local communities. Most case studies focus on the socioeconomic functions of the buffer zone and overwhelmingly report lack of success in implementation (Martino, 2001). We propose that scientifically-based designation of a zone of interaction may overcome these difficulties. Rather than limiting land uses and access over a broadly-defined buffer, a ZOI approach can more specifically target locations and processes of particular importance for the ecological integrity of protected areas. Restrictions for local communities can be more targeted towards those places and land uses that are most important for conservation.

Designation of a zone of interaction is based on four primary mechanisms through which land use change outside a PAs boundaries affects its function (Hansen and DeFries, 2007). First, land use change may reduce the effective size of habitat, resulting in extirpation of species with large home ranges, simplified trophic structure, reduced species richness, and inability to maintain multiple seral stages, e.g. (Terborgh, 1990; Vester et al., 2007). Second, land use change can alter flows of water, air, fire and other materials in and out of the protected area, such as dams that sever hydrologic connectivity (Freeman et al., 2007). Third, crucial habitats outside the protected area, such as seasonal habitats, migration routes, or habitats for source populations can be eliminated or made inaccessible by land use change. In East Africa, for example, dry-season habitat for wildebeest outside of the Masaai Mara protected area boundaries were converted into agricultural land (Serneels and Lambin, 2001). Finally, human activity within and along the borders of protected areas can result in invasive species, increased hunting and poaching, and other activities detrimental to wildlife.

Globally, protected areas occur in a wide variety of physical and socioeconomic settings. It is not possible to generalize management opportunities for balancing human needs and conservation goals within the ZOI across different settings. DeFries et al. (2007) distinguish management opportunities according to different socioeconomic settings. Protected areas in remote locations with low human population density require minimal management with infrequent monitoring. Extractive frontier landscapes with active agricultural expansion, logging, and mining, such as is currently the case in the southern Amazon, require protection of critical habitats and corridors with frequent monitoring. Protected areas in high density of affluent populations with second homes, recreation and tourism present opportunities for conservation easements and development concentrated away from crucial habitats in the surrounding area, such as in the Greater Yellowstone Ecosystem (Gude et al., 2007).

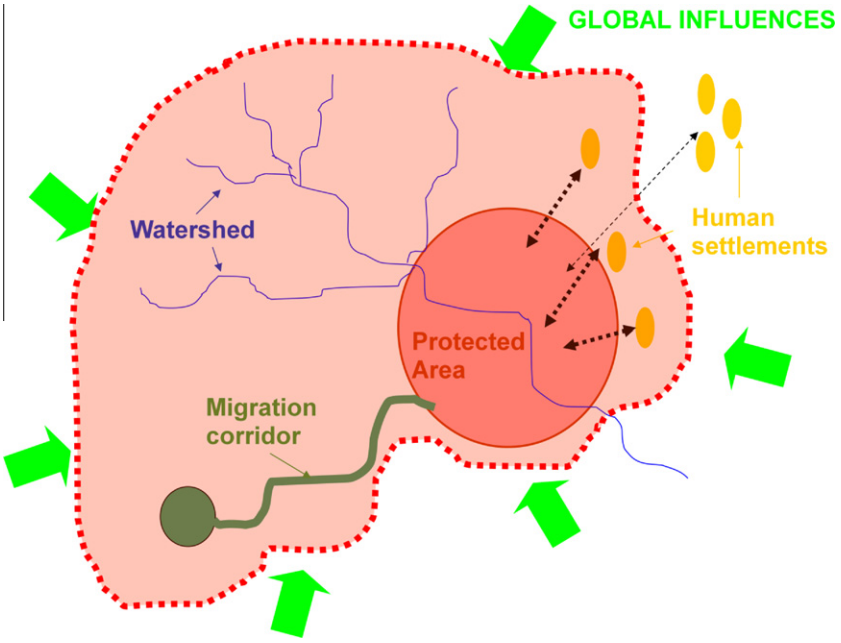

Fig. 1. Schematic representation of a zone of interaction (red dotted line) based on hydrologic, ecologic, and socioeconomic interactions between a protected area and its surroundings. Thick dotted black line indicates strong socioeconomic interactions such as fuelwood collection, grazing, and resource extraction from nearby communities. Thin black dotted line represents weaker socioeconomic interactions. The ZOI is influenced by regional and global factors such as climate change and atmospheric transport (green arrows). Adapted from (DeFries et al., 2009).