The importance of incorporating threat for efficient targeting and evaluation of conservation investments

Adina Maya Merenlender[1], David Newburn[2], Sarah E. Reed[1], & Adena R. Rissman[3]

[1] Environmental Science, Policy, and Management Department; UC Berkeley, Berkeley, CA 94720-3114, USA
[2] Department of Agricultural Economics, Texas A&M, 352B Blocker 2124 TAMU, College Station, TX 77843-2124, USA
[3] Forest and Wildlife Ecology, University of Madison, Wisconsin 111 Russell Labs, 1630 Linden Drive Madison, WI 53706, USA

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Correspondence
Adina Maya Merenlender, ESPM MC3114, UC Berkeley, Berkeley CA 94720-3114, USA. Tel: 707–744-1424; fax: 7077441040. E-mail: adina@nature.berkeley.edu

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We commend Underwood *et al.* (2009) for evaluating investment returns on billions of public dollars spent on land conservation by comparing actual with optimal conservation spending. However, they use a "maximize gain" prioritization strategy (Murdoch *et al.* 2007) that omits the likelihood of land-use conversion in the optimization algorithm, thereby implicitly assuming that all areas have the same probability of future development. Because development threat and cost are positively correlated, the "maximize gain" strategy is biased toward inexpensive land where biodiversity is more likely to remain without conservation expenditure.

As Wilson *et al.* (2006) note, the "maximize gain" algorithm underperforms when allocating conservation expenditures where threat is highly variable. Using parcel-level data in Sonoma County, California, we demonstrated that a dynamic reserve site selection model incorporating threat, costs, and benefits significantly outperformed the "maximum gain" approach (costs and benefits only) (Newburn *et al.* 2006). In California, the same land-cover change data sets used by Underwood *et al.* (2009) reveal that the threat of habitat conversion varies substantially from almost none to 0.53% conversion of developable land per year among counties (FMMP 2002; C-CAP 2003; see Figure S1). The California data used by Underwood *et al.* (2009) also show the expected positive correlation between the threat of urban conversion and land cost (see Figure S2). Since these high vulnerability sites are typically more expensive than low vulnerability sites, they will be excluded by the "maximize gain" approach.

Because the rate of habitat loss was not included, counties prioritized by Underwood *et al.* (2009) were less threatened than average, with a mean rank of 33.5 out of 50 counties for their annual rate of habitat conversion. These counties lost an estimated 134 ha per year of habitat to urban development, compared to an average of 1,234 ha per year in the ten fastest-growing counties. Colusa County, which was selected by both funding scenarios in Underwood *et al.* (2009), was ranked 47th for its annual rate of habitat loss to urban development; in contrast, San Bernardino County, which has high species richness, moderate land costs, and lost the greatest total amount of habitat each year was not selected.

The "maximize gain" strategy can be appealing to investors in private land conservation because it results in large landscape acquisitions. For example, close to US$13 million of public funding was used to purchase over 37,000 hectares of conservation easements in Tehama County between 1997 and 2007. However, these actions

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are expected to have little effect on future rates of habitat loss because of low human population growth projections and existing land-use policies (Byrd *et al.* 2009). Due to the low land values in this area, the "cost-efficient" funding scenario proposed by Underwood *et al.* (2009) would increase investment levels in Tehama County to $360 million.

Of course, despite high threat levels, some sites come at too high a price. Therefore, spatial conservation targeting models must attempt to minimize loss by making trade-offs between land costs, biological benefits, and the probability of habitat loss, which generally result in prioritizing biodiversity-rich areas in moderate-to-high threat sites and for moderate costs (Newburn *et al.* 2005).

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1: Annual rate and rank order of conversion from natural to urban land cover in 50 California counties between 1990 and 2004. The rate of land cover change was calculated as a percentage of the total developable land in each county, excluding public lands and protected areas. Analysis is limited to urban conversion because there was greater agreement between the two data sources, which cover different geographic areas (FMMP 2002; C-CAP 2003).

Figure S2: Annual rate of urban conversion rate versus land costs, fitted with linear regression ($R^2 = 0.3$). Land costs are taken from Table S1 in supplemental materials from Underwood *et al.* (2009). Annual rate of urban conversion between 1990 and 2004 is derived from FMMP (2002) and C-CAP (2003), as shown in Figure S1.

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